



**December 2017/January 2018 Issue**

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<http://www.acs.org/chemmatters>

**Teacher’s Guide**



**Teacher's Guide for**

### *“Got Vitamin D?”*

**December 2017/January 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Biochemistry** | The chemistry of vitamin D could be included in a unit on biochemistry when vitamins are discussed. |
| **Chemical reactions** | The conversion of 7- dehydrocholesterol to vitamin D3 can be used as an example of a photochemical (light-initiated) reaction during lessons on chemical reactions. If teaching organic reactions, it can be used as an example of an organic fission reaction. |
| **Organic chemistry** | The comparison of the structures of vitamins D2 and D3 can be used when talking about organic structures and substitution groups like the methyl groups on the compound. The hydroxyl groups on the compounds are examples of a functional group the students could identify. |

# Teaching Strategies and Tools

* Links to **Common Core Standards for Reading**:

**ELA-Literacy.RST.9-10.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**ELA-Literacy.RST.9-10.5.** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, and energy).

**ELA-Literacy.RST.11-12.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

**ELA-Literacy.RST.11-12.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

* Links to **Common Core Standards for Writing**:

**ELA-Literacy.WHST.9-10.2F.** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

**ELA-Literacy.WHST.11-12.1E.** Provide a concluding statement or section that follows from or supports the argument presented.

* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:

**ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.

**ELA-Literacy.WHST.11-12.1.A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

* Links to **Next Generation Science Standards**:

**HS-LS1-4:** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

* **Disciplinary Core Ideas:**
  + LS1.A: Structure and Function
* **Crosscutting Concepts:**
* Cause and effect: Mechanism and explanation
* Systems and system models
* Structure and function
* **Science and Engineering Practices:**
* Constructing explanations and designing solutions
* Obtaining, evaluating, and communicating information
* **Nature of Science:**
* Scientific knowledge assumes an order and consistency in natural systems

## Vocabulary Vocabulary and concepts that are reinforced in the December 2017/January 2018 issue:

* Metric units
* Structural Formulas
* Fermentation
* pH
* Electrochemistry
* Oxidation & Reduction
* Amines
* Allotropes
* Physical properties
* London dispersion forces

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 8):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.
* **Graphic Organizer (p. 9):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers 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 |

* **Student Reading Comprehension Questions (p. 10):** The Student Reading Comprehension Questions are designed: to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.
* Most of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make decisions in their personal lives.
* Consider asking students to read “Open for Discussion: Are Vitamin Supplements Necessary?” on page 4 to extend the information in “Got Vitamin D?” on pages 5-6.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.

“Got Vitamin D?” *ChemMatters*, December 2017/January 2018 Issue

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

“A Close-up Look at the Quality of Indoor Air” (*ChemMatters*, April/May 2016 Issue)

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. 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. Our bodies can produce both vitamin D2 and vitamin D3 when we are in sunlight. |
|  |  | 1. Vitamin D produced by our bodies is derived from cholesterol. |
|  |  | 1. Fatty fish are good sources of Vitamin D. |
|  |  | 1. The FDA (Food and Drug Administration) regulates foods that are fortified with vitamin D. |
|  |  | 1. In the U. S., vitamin D fortification of infant formula is required. |
|  |  | 1. Less than 25% of the adult population takes supplemental vitamins. |
|  |  | 1. Vitamin D helps produce strong bones even if we do not eat enough calcium. |
|  |  | 1. People over 70 years old do not need as much vitamin D as younger people. |
|  |  | 1. Research suggests that daily sun exposure is required to produce adequate levels of vitamin D. |
|  |  | 1. It is possible to overdose on vitamin D from supplements. |

## Graphic Organizer

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

“Got Vitamin D?” *ChemMatters*, December 2017/January 2018 Issue

**Directions**: ***As you read***, complete the graphic organizer below to describe where we obtain vitamin D and why we need it.

|  |  |
| --- | --- |
| **Vitamin D** |  |
| **Sources** |  |
| **How our bones use it** |  |
| **Effects of overdose** |  |

**Summary:** On the back of this paper, use information from the article to write a tweet (280 characters or less) about vitamin D.

## Student Reading Comprehension Questions

“Got Vitamin D?” *ChemMatters*, December 2017/January 2018 Issue

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

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

* 1. When does the body produce vitamin D?
  2. What are the best dietary sources of vitamins D2 and D3?
  3. Give several examples of foods that are vitamin D fortified.
  4. For what food does the U.S. Food and Drug Administration mandate the addition of   
     vitamin D?
  5. What disease is caused by a vitamin D deficiency?
  6. What is the composition of the outer layers of bones?

**Student Reading Comprehension Questions, cont.**

“Got Vitamin D?” *ChemMatters*, December 2017/January 2018 Issue

* 1. How does vitamin D affect the supply of calcium ions (Ca2+) and phosphate ions (PO43–) in the blood?
  2. What causes the bones to become soft, and why is this a problem?
  3. How much sun exposure is recommended to produce adequate levels of vitamin D?
  4. What are the symptoms of vitamin D toxicity or hypervitaminosis D?
  5. What level of vitamin D causes toxicity?
  6. What is the recommended daily dose of vitamin D for the average high school student?

## Answers to Student Reading Comprehension Questions

1. **When does the body produce vitamin D?**

*The body only produces vitamin D when the skin is exposed to ultra-violet (UV) light from the sun.*

1. **What are the best dietary sources of (a) vitamin D2, and (b) vitamin D3?**
   1. *The dietary sources of vitamin D2 are vegetables such as mushrooms and alfalfa.*
   2. *The dietary sources of vitamin D3 are the flesh of fatty fish such as salmon, tuna, and mackerel as well as fish liver oils.*
2. **Give at least four examples of foods that are vitamin D fortified.**

*Some examples of vitamin D fortified foods are*

1. *milk*
2. *milk substitutes*
3. *breakfast cereals*
4. *pastas*
5. *yogurts*
6. *some cheeses*
7. *some juices*
8. *margarine spreads.*
9. **For what food does the U.S. Food and Drug Administration mandate the addition of vitamin D?**

*In the U.S., the Food and Drug Administration mandates that infant formula is fortified with vitamin D due to the importance of vitamin D in young children.*

1. **What disease is caused by a vitamin D deficiency?**

*Vitamin D deficiency can result in a disease called rickets, which causes bones to be too soft.*

1. **What is the composition of the outer layers of bones?**

*The outer layers of bones are composed of collagen and hydroxyapatite, a calcium phosphate salt [Ca10(PO4)6(OH)2].*

1. **How does vitamin D affect the supply of calcium ions (Ca2+) and phosphate ions (PO43–) in the blood?**

*Vitamin D helps increase the levels of calcium and phosphate ions in the blood by aiding in the absorption of these ions in the intestines, as well as increasing the reabsorption of calcium ions in the kidneys.*

1. **What causes the bones to become soft, and why is this a problem?**

*“When vitamin D levels are low, there is relatively little hydroxyapatite compared with collagen, so bones become soft.” Soft bones are pliable, so their shape can change under a person’s weight. Bowed legs may result from vitamin D deficiency. Note that students may also answer that low vitamin D levels reduce the deposit of calcium ions on the outer layer of bones, making them soft, which can be inferred from the diagram at the top of page 6 in the article.*

1. **How much sun exposure is recommended to produce adequate levels of vitamin D?**

*According to the results of research reported in this article, adequate levels of vitamin D can be produced by approximately 5–30 minutes of sun exposure between 10 am and 3 pm at least twice a week*

*.*

1. **What are the symptoms of vitamin D toxicity or hypervitaminosis D?**

*According to the author, “Symptoms of vitamin D toxicity, or hypervitaminosis D, include feeling tired: nausea, vomiting, and dizziness; increased blood pressure; and/or an irregular heartbeat.”*

1. **What level of vitamin D intake has been reported to cause~~s~~ toxicity?**

*Vitamin D toxicity has been shown to result from taking 50,000 international units (IU) a day of vitamin D for several months. This is about 100 times the recommended daily allowance.*

1. **What is the recommended daily vitamin D dose for the average high school student?**

*The recommended daily vitamin D dose for an average high school student is 600 IU, or   
15 µg/day.*

# Possible Student Misconceptions

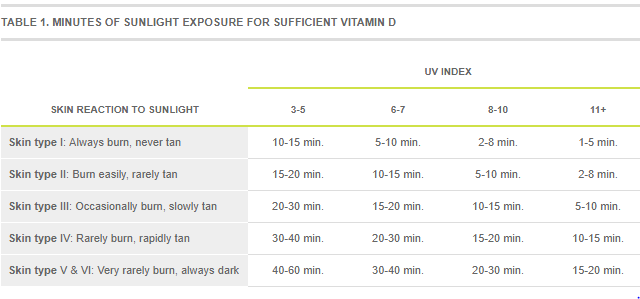
1. **“I’ve always heard that sunlight contains vitamin D.”** *Sunlight is radiant energy and does not contain any chemical compounds. The reaction of 7-dehydrocholesterol in your skin with the sunlight is what produces the vitamin D.*
2. **“I should go without sunscreen in order to get my vitamin D.”** *While it is true that you will produce more vitamin D if you are not wearing sunscreen*, *sunscreen is important in protecting your skin from the damaging effects of the sun. Sunscreen generally does not block all the UV— just 93–98% of it—depending on the sun protection factor (SPF). Plus, this advertised percentage of blockage relies on proper application and usage. Your skin will still be able to produce some vitamin D, even while wearing sunscreen, but probably not an adequate amount—unless you are spending a lot of time outdoors. While some professionals say spending only 15–30 minutes in the sun twice a week without sunscreen is enough to produce an adequate amount of vitamin D, you should be careful about the amount of time you spend in the sun without sunscreen, protective clothing, and sunglasses. Overexposure to the sun causes the skin to toughen and age prematurely and increases the risk of developing skin cancer. Also, overexposure of the eyes to sunlight can cause cataracts to develop. The American Academy of Dermatology’s 2009 “Position Statement on vitamin D” concluded that “there is no scientifically validated, safe threshold level of UV exposure from the sun that allows for maximal vitamin D synthesis without increasing skin cancer risk.”* *The Skin Cancer Foundation recommends that one get vitamin D from diet and supplements rather than to rely on sun exposure, which can lead to skin cancers*. ([*http://www.skincancer.org/healthy-lifestyle/vitamin-d/damage*](http://www.skincancer.org/healthy-lifestyle/vitamin-d/damage)*)*
3. **“I drink lots of milk and get enough vitamin D from my diet, so I don’t need to expose myself to the sun.”** *It is difficult to get enough vitamin D from your diet alone unless you drink six glasses of milk and a couple of helpings of salmon every day. If you are going to rely on diet alone you may want to take cod liver oil or another vitamin D supplement to make sure you are getting enough vitamin D.*
4. **“Vitamin D is similar in function to all the other vitamins.”** *Vitamin D is different from all the other vitamins, both in structure and in function. Vitamin D is the only vitamin that can be synthesized by the body. All the others can only be acquired by diet. Many vitamins like the B vitamins are cofactors in enzymatic reactions while some like vitamins C and E act as antioxidants. Vitamin D is a unique vitamin in that it is really a prohormone. By itself it is inactive and requires the addition of two hydroxyl groups to become functional. The first hydroxyl group is added in the liver while the second hydroxyl group is added in the kidney. The active form of vitamin D is a steroid that functions in the endocrine system. Active vitamin D binds to a carrier protein, where it is transported throughout the body. It is responsible for absorption of calcium and phosphate ions in the intestines as well as the retention of calcium by the kidneys. It functions intracellularly in the transcription of DNA to activate or suppress many genes. We are just beginning to understand the multiple functions of this prohormone.*

# Anticipating Student Questions

1. **“Does vitamin D2 behave the same way as vitamin D3 in the body?”** *Vitamin D2 affects the same mechanisms for calcium and phosphate retention as vitamin D3 so, in this respect, they behave functionally the same. Vitamin D3 is made by the body when the skin is exposed to UVB radiation, and the body is tailored for this form. The plant-produced vitamin D2 does not bind as well to the receptors in human tissues compared to D3, due to a slight difference in molecular structure. Also, D2 has a shorter half-life in the body because D2 is deactivated and rendered irretrievable sooner than D3. Overall, D3 is 300% more effective than D2.*
2. **“If I can’t be outside between 10 am and 3 pm, can I get enough sunlight during the other hours of the day to produce sufficient vitamin D?”** *During the recommended hours, the percentage of radiation that is attributed to UVB is 5%. Times outside this window have only 1% UVB radiation. UVA makes up the balance of the UV radiation to which you are exposed. It would take much longer to produce the same amount of vitamin D3 that can be produced in 15–20 minutes during these peak hours of maximum sunlight. The average person produces 10,000 IU of vitamin D3 in 15–20 minutes during these times.*

“*Regarding the amount of vitamin D production in human skin, it depends on several variables including environmental factors such as geographic* latitude*,* season*, time* of day*,* weather conditions *(cloudiness), amount of* air pollution *and* surface reflection *which can all interfere with the amount of UVB radiation reaching the skin.*” *(*[*http://www.sciencedirect.com/science/article/pii/S209012321400023X*](http://www.sciencedirect.com/science/article/pii/S209012321400023X)*)*

1. **“Do vitamin D levels vary according to climate and geographical location?”** *Vitamin D levels will vary as a function of climate and/or geographical location. Latitudes near the equator receive more sunshine, and populations in those areas generally have higher levels of vitamin D. Northern latitudes receive less sunshine, so populations there have lower vitamin D levels. Altitude also affects the amount of UVB that reaches the earth’s surface. In mountainous regions of high altitude, the atmosphere is thinner and more UVB gets to the earth’s surface. Mountainous populations thus often have higher vitamin D levels. Increased cloud cover or pollution that screens out some of the UVB can be responsible for decreasing vitamin D production in affected populations. However, not all people who live in sunny locations have high vitamin D levels. In Saudi Arabia, which is one of the sunniest spots in the world, 90% of the population is vitamin D deficient. Dress and lifestyle may also play a part here, as Saudi Arabians expose little skin to the sun and spend a good amount of time indoors out of the heat.*
2. **“Do people have seasonal variation in vitamin D levels?”** *People who live in the northern hemisphere and spend a considerable amount of time indoors during the winter months of the year can show a seasonal variation in their vitamin D level if they are not taking vitamin D supplements. The further you get from the equator, the more pronounced the seasonal variation in vitamin D levels becomes. In those areas, vitamin D levels decline during the winter months.*
3. **“Can you get vitamin D toxicity by spending too much time outdoors?”** *Vitamin D toxicity would be difficult to acquire by spending too much time outdoors. Besides vitamin D3, other compounds are also formed. These substances are part of a feedback loop that shuts down the production of vitamin D3 after maximal levels are reached. Vitamin D toxicity is usually obtained after several months of high doses of vitamin D supplements. (*<http://www.sciencedirect.com/science/article/pii/S209012321400023X>*)*
4. **“I have bowed legs, does that mean I had rickets?”** *All bowed legs are not necessarily caused by the vitamin D and calcium deficiency seen in rickets. Due to their position in the uterus, most babies are born with bowed legs. The legs usually straighten with time. Breastfed babies whose mother’s milk does not contain enough vitamin D or calcium are most at risk for developing varying degrees of rickets. However, there are other conditions that cause bowing of the legs. Blount’s disease causes the tibia to grow in a way that causes the legs to bow. Leg braces are usually used to treat this disorder. Sometimes bowed legs can be acquired due to the way the legs are used over time, such as in the bowed legs of many horse jockeys.*
5. **“If I have applied sunscreen, will my skin still be able to make vitamin D?”** *Your skin will still be able to make some vitamin D after sunscreen is applied, but not as well as it does without sunscreen, and adequate levels of vitamin D may not be produced, unless you are spending a lot of time outdoors. Sunscreen creates a barrier between the skin and the UV radiation from the sun. This protects the skin, but it prevents the reaction that produces vitamin D; however, the way that most people use sunscreen—too lightly applied and not often enough—not all UVB radiation will be blocked by wearing sunscreen. Well applied sunscreen typically blocks between 93–98% UVB. Some resources recommend getting 15–30 minutes of sun without sunscreen twice a week, but then protecting your skin with sunscreen afterward. The position of the American Academy of Dermatology is that “there is no scientifically validated, safe threshold level of UV exposure from the sun that allows for maximal vitamin D synthesis without increasing skin cancer risk.” They recommend getting vitamin D through diet and supplements.*
6. **“How much skin needs to be exposed for adequate vitamin D production to take place?”** *How much skin needs to be exposed depends on the UV index, which is dependent on the time of day and the season. Also, vitamin D production varies in different skin types. People with very fair skin need less exposure than do people with darker skin. The different times for sun exposure for each skin type are given in the table on the next page. The recommendations in the chart assume exposure to this amount of sunlight three times per week while wearing a T-shirt and shorts, without applying sunscreen. The UV index is highest between 10 am and 4 pm during the summer months. (*[*https://www.gbhealthwatch.com/Did-you-know-Get-VitD-Sun-Exposure.php*](https://www.gbhealthwatch.com/Did-you-know-Get-VitD-Sun-Exposure.php)*)*



1. **“Does my skin make vitamin D when it is exposed to the UV lights of a tanning bed?”** *If the tanning bed emits some UVB, then your skin will produce vitamin D. Tanning beds primarily use UVA but some UVB is usually present in most beds. Combination tanning beds (those with bulbs that emit both UVA and UVB rays) emit between 93–99% UVA and 1–7% UVB. It has been found that people who regularly use tanning beds that emit UVB radiation have higher vitamin D concentrations, but they also have higher incidences of skin cancer.*

# Activities

**Labs and demos**

**Experiments with UV-sensitive beads:** Demonstrate the effectiveness of a variety of sunscreens with different SPF ratings using plastic bags filled with UV-sensitive beads. One procedure for doing this as a teacher demonstration can be found here: <https://www.stevespanglerscience.com/lab/experiments/uv-reactive-beads/>.

Or, instructions for setting it up as an inquiry style lesson that encourages students to design their own procedures to test variables such as sunscreen, eyeglasses, sunglasses, clothing, and water can be found here: <http://solar-center.stanford.edu/activities/UVBeads/UV-Bead-Instructions.pdf>.

**“The Photochemical Redox Reactions of Thionin”:** Light from an overhead projector (or light box?) initiates the reaction that changes a colorless thionin solution to blue. This reaction, the procedure for which can be found in an online book of chemical demonstrations, can be used as a teacher demonstration simulating how the reaction of 7-dehydrocholesterol to vitamin D3 is initiated by UVB light. (<http://www.cee.org/tep-lab-bench/pdf/Demo.Manual.CPS.pdf>; note this source includes many other demonstrations that may be useful to you.)

**Media**

**“Understanding Vitamin D” video (6:18):** An advanced presentation about the metabolism of vitamin D in the body and its multiple functions, the video contains animated diagrams that show the intracellular reactions of vitamin D. The explanations are thorough, yet not too complex. <https://www.youtube.com/watch?v=onSPZ0aBUKM>

**“D News” video (4:15):** This fast-paced video could be used as a fun infomercial to recap much of what is written in the Warmflash vitamin D article. In the course of the segment, it emphasizes that many foods are fortified with vitamin D2, rather than vitamin D3. Students could fact check this claim by reading food labels. (<https://www.youtube.com/watch?v=4VlXGA1FnSk>)

**“Hydrogen and Chlorine Reaction” video (2:56):** This explosive chemical reaction demonstrates the power and speed of a photochemical reaction. Molecular hydrogen and chlorine are placed in a stoppered test tube and exposed to red, yellow, green, blue, and ultraviolet light to show the wavelength specificity of the reaction; typically, only the UV light has sufficient energy to initiate the reaction. (<https://www.youtube.com/watch?v=NN82GoBG98s>)

**Lessons and lesson plans**

**“Teen Years: A Once in a Lifetime Chance to Build Bone”:** This set of learning activities includes a PowerPoint presentation with accompanying presentation notes, lesson plan, and resources to present lessons around building bone in the teen years. The roles of calcium and vitamin D are a significant portion of the lesson. (<https://bcdairy.ca/nutritioneducation/lesson-plans#secondary>) Additional resources referred to in these lessons: <https://bcdairy.ca/nutritioneducation/calciumcalculator/> and <http://www.eatracker.ca/food_search.aspx>.

**A TED-Ed lesson on how vitamins work:** A short video (4:43) titled “Vitamins” is accompanied by three written segments “Think”, “Digging Deeper”, and “Discuss”, which contain questions for students to answer, links for students to search for more information, and a final topic to discuss. (<https://ed.ted.com/lessons/what-s-the-value-of-vitamins-ginnie-trinh-nguyen#watch>)

**Projects and Extension Activities**

**“When Something’s Missing: Exploring Vitamin Deficiencies”:** Students research various vitamin deficiencies using links to several *New York Times* articles. Suggestions for class activities include having students keep a food diary and analyze it using some tools provided. (<https://learning.blogs.nytimes.com/2012/03/14/when-somethings-missing-diagnosing-vitamin-deficiencies/>)

**Make UV sensitive blueprint paper:** Students experiment with the photochemical reaction present in making blueprints in this lab, analogous to the photo-initiated reaction of sunlight helping the body produce vitamin D. The instructions to this lab are thorough and include alternate formulas for the sensitizer solution to accommodate different stockroom supplies. (<http://www.sserc.org.uk/chemistry-resources/1347-chemistry-workshops/3797-cyanotypes>)

**“Basic Vitamins: Water-Soluble and Fat-Soluble”:** This plan from Utah Education Network concerns the functions and sources of vitamins and their roles regarding maintenance of optimum health. The lesson plan lists eight optional activities and provides written materials that accompany them. (<http://www.uen.org/Lessonplan/preview.cgi?LPid=1261>)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

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Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



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In the “Open for Discussion” segment of this issue, the authors discuss UV radiation as it relates to students tanning themselves in preparation for the prom. There is a good chart of the percentage of UV-A and UV-B present in sunlight at various times of day. The interaction between UV-B and the skin to produce vitamin D3 is mentioned. (Sitzman, B.; Goode, R. A Tan—Quick, Easy, and Safe? *ChemMatters,* 2012, *30* (1), p 5)

The difference in vitamin D levels in African-Americans compared to Caucasians is discussed in a sidebar of this article about the chemistry of skin color. African-Americans have lower vitamin D levels, yet denser and stronger bones. The difference in levels of a vitamin D carrier protein may help explain this phenomenon. (Harper, K. Skin Color: A Question of Chemistry. *ChemMatters*, 2014, *32* (2), pp 12–14).

# Web Sites for Additional Information

**Vitamin D**

**“**Vitamin D and the Skin: Focus on a Complex Relationship” presents extensive information about vitamin D, with a special look at its immune function. The article contains an extensive list of skin disorders that may be linked to low levels of vitamin D. (<http://www.sciencedirect.com/science/article/pii/S209012321400023X>)

This publication from the National Institute of Health, “Dietary Reference Intakes for Calcium and Vitamin D”, contains extensive information about vitamin D. It addresses all aspects of vitamin D, from metabolism, to function, to variations in production among races, and it includes some diagrams of the chemical pathways involved in vitamin D synthesis and metabolism that might be useful when explaining these to students. (<https://www.ncbi.nlm.nih.gov/books/NBK56061/>)

**Vitamin D—actually, a hormone, NOT a vitamin**

Vitamin D is actually a hormone rather than a vitamin. The Society of Endocrinology provides information about how vitamin D functions as a hormone in the body at this site: <http://www.yourhormones.info/hormones/vitamin-d/>.

“From Vitamin D to Hormone D: Fundamentals of the Vitamin D Endocrine System Essential for Good Health” reveals that vitamin D initiates the physiologic response of more than 36 cell types that contain the vitamin D receptor protein. Vitamin D has an extensive role in the health of many systems within our bodies. (<http://ajcn.nutrition.org/content/88/2/491S.long>)

**Vitamin D variations in different skin colors**

The article “Skin Color Adaptation” attributes variations in vitamin D levels in different races to the evolutionary differences in the amount of melanin in the skin. The article includes a map of the world showing the geographic distribution of skin color across the globe. (<https://www2.palomar.edu/anthro/adapt/adapt_4.htm>)

The article “Vitamin D Photosynthesis and Skin Pigmentation” cites several research studies that refute the claim that difference in skin pigmentation evolved due to the need for vitamin D. One study found the amount of cholesterol in the skin was more closely correlated to skin vitamin D levels than pigmentation. (<https://www.chronicillnessrecovery.org/index.php?option=com_content&view=article&id=297%3Avitamin-d-photosynthesis-and-skin-pigmentation&catid=1%3Ageneral&Itemid=5>)

**Vitamin D2 vs vitamin D3**

Several scientific studies show that vitamin D3 is more effective than vitamin D2 as a supplement to increase serum vitamin D levels. This research paper is a meta-analysis of these studies. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3349454/>)

“Vitamin D3 vs. Vitamin D2—What’s the Difference?”compares of the efficacy of vitamin D3 vs vitamin D2 showing that vitamin D3 supplements are better at raising the vitamin D levels in humans. The site also contains re is a list of 11 references from well-known refereed journals at the end of the article to support the conclusion.

(<https://www.globalhealingcenter.com/natural-health/vitamin-d3-vs-vitamin-d2/>)

**Vitamin D toxicity**

Vitamin D toxicity does not come from overexposure to the sun but from over-supplementing with vitamin D. In the report “Vitamin D: A Rapid Review”, one segment is devoted to discussing vitamin D toxicity. ([http:www.medscape.com/viewarticle/589256\_10](http://www.medscape.com/viewarticle/589256_10))

**Rickets**

The link between vitamin D and rickets has been known since the early 1900s. The vitamin D council presents thorough information on rickets: diagnosis, prevention, treatment, and research results. (<https://www.vitamindcouncil.org/health-conditions/rickets/>)

The rickets Wikipedia Web page contains extensive information that includes historical anecdotes, as well as a discussion on the evolutionary hypotheses surrounding vitamin D deficiencies and skin pigmentation. (<https://en.wikipedia.org/wiki/Rickets>)

**Sunlight requirements for vitamin D synthesis**

“The Required Vitamin D per Day” appears in the San Francisco journal *SFGATE*.

Besides information on vitamin D requirements, there are over 15 links to other articles concerning vitamin D. (<http://healthyeating.sfgate.com/required-vitamin-d-per-day-4314.html>)

This site contains an excellent table on the amount of sun exposure required for sufficient vitamin D synthesis, based on skin type and UV index. It explains the UV index and includes a link to a Web site that will help you find the UV index for your location at any given time and date. (<https://www.gbhealthwatch.com/Did-you-know-Get-VitD-Sun-Exposure.php>)

**Interactive nutrition calculators**

The “Calcium Calculator” is an interactive tool that students can use to calculate the calcium in their diets to see if they are getting enough. Students can draft and print plans of changes to make in their diets. (<https://bcdairy.ca/nutritioneducation/calciumcalculator/>)

The “Eat Tracker” is an interactive tool students can use to look up the nutritional information of various foods, calculate BMI, and learn the number of calories expended by different activities. It is also possible to enter recipes and get their food value analyzed. (<http://www.eatracker.ca/food_search.aspx>)

**Vitamin D research**

This site has a tab, labeled “Research”, which contains a plethora of information describing what is known about supplementation with vitamin D. A table of contents at the beginning of the section makes looking for specific information quick and easy. (<https://examine.com/supplements/vitamin-d/>)

An infographic titled “Snake Oil Supplements: Scientific Evidence for Popular Health Supplements” consists of various dietary supplements or foods in interactive dots that, when clicked upon, reveal a recent study about that constituent. The supplements are arranged by level of supporting evidence for the claim. (<http://www.informationisbeautiful.net/visualizations/snake-oil-scientific-evidence-for-nutritional-supplements-vizsweet/>)

# About the Guide

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.



**Teacher's Guide for**

### *“Cheesy Science!”*

**December 2017/January 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **pH** | The fermentation of cheese is highly dependent upon the pH conditions during the reaction. This article provides students with a practical and relatable example of how varying the pH causes reactions to change, and produce different results. |
| **Polar molecules** | An example of the polarity of molecules is found in the formation of micelles of casein in making cheese. The hydrophobic and hydrophilic nature of molecules due to their polarity has a profound effect on solubility, mixtures, and biochemical processes. |
| **Biochemistry** | The action of rennin (an enzyme), casein (a protein), and peptide bonds; the human use of microbial reactions to alter foods; and the dependence of living organisms on proper pH illustrate many aspects of biochemistry, through the study of cheesemaking. |
| **Rates of reaction** | The variables affecting the rate and success of cheese production that are discussed in the article are great examples of factors affecting reaction rates in general. |
| **Relationship between H+ and OH– in water solutions** | The article shows an excellent chart illustrating the relationships among pH, OH– concentration, and H+ concentration. This visual aid may provide students with a way to better understand acids and bases. |
| **Peptides and amino acids** | The production of cheese from the milk protein, casein, is a practical example of peptides, peptide bonds, and the constituent amino acids. When aging cheese, the article provides information on how proteins are converted by bacteria into peptides, then amino acids, and then into amides that influence the taste and texture of these aged cheeses. |
| **Enzymes as catalysts** | While the article does not identify it as such, rennin is a biological catalyst found in rennet. Students may be familiar with inorganic catalysts, but biological catalysts (enzymes) may be a less familiar example. |

# Teaching Strategies and Tools

* Links to **Common Core Standards for Reading**:

**ELA-Literacy.RST.9-10.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**ELA-Literacy.RST.9-10.5.** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, and energy).

**ELA-Literacy.RST.11-12.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

**ELA-Literacy.RST.11-12.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

* Links to **Common Core Standards for Writing**:

**ELA-Literacy.WHST.9-10.2F.** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

**ELA-Literacy.WHST.11-12.1E.** Provide a concluding statement or section that follows from or supports the argument presented.

* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:

**ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.

**ELA-Literacy.WHST.11-12.1.A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

* Links to **Next Generation Science Standards**:

**HS-PS1-5:** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

* **Disciplinary Core Ideas**:
* PS1.A: Structure and properties of matter
* PS1.B: Chemical reactions
* **Crosscutting Concepts:**
* Scale, proportion, and quantity
* **Science and Engineering Practices:**
* Asking questions (for science) and defining problems (for engineering)
* Analyzing and interpreting data
* **Nature of Science:**
* Scientific knowledge assumes an order and consistency in natural systems

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the December 2017/January 2018 issue:

* Metric units
* Structural Formulas
* Fermentation
* pH
* Electrochemistry
* Oxidation & Reduction
* Amines
* Allotropes
* Physical properties
* London dispersion forces

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 31):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.
* **Graphic Organizer (p. 32:** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers 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 |

* **Student Reading Comprehension Questions (p. 33-34):** The Student Reading Comprehension Questions are designed to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.
* Most of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make decisions in their personal lives.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.

“Cheesy Science!” *ChemMatters*, December 2017/January 2018 Issue

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. 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. Cheese consumption in the U. S. is down from 30 years ago. |
|  |  | 1. All cheese comes from the milk of mammals. |
|  |  | 1. Bacteria are required to make cheese. |
|  |  | 1. Milk is slightly basic. |
|  |  | 1. Bacteria that grow best in moderate temperatures (between 20 and 45°C) are used to make sharp cheeses like Parmesan and romano. |
|  |  | 1. As sugar ferments, the solution becomes more acidic. |
|  |  | 1. People who are lactose intolerant can eat aged cheese. |
|  |  | 1. Rennet, an enzyme used to speed up the curdling process, comes from a calf’s stomach. |
|  |  | 1. All cheeses acidify from milk at the same rate. |
|  |  | 1. Some hard cheeses may be aged for decades. |
|  |  |  |

“Cheesy Science!” *ChemMatters*, December 2017/January 2018 Issue

## Graphic Organizer

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

**Directions**: ***As you read***, ***As you read***, complete the graphic organizer below to compare the chemistry of how hard and soft cheeses are produced.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Examples of hard cheese*** | ***Steps to produce hard cheese*** | ***pH*** | ***Temperature*** | ***What happens in this step*** |
|  | Adding bacteria |  |  |  |
| Creating curd (coagulation) |  |  |  |
| Finishing cheese |  |  |  |
| ***Examples of hard cheese*** | ***Steps to produce soft cheese*** | ***pH*** | ***Temperature*** | ***What happens in this step*** |
|  | Adding bacteria |  |  |  |
| Creating curd (coagulation) |  |  |  |
| Finishing cheese |  |  |  |

**Summary:** On the back of this paper, write three new things you learned about making cheese that would like to share with a friend.

## Student Reading Comprehension Questions

“Cheesy Science!” *ChemMatters*, December 2017/January 2018 Issue

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

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

1. On average, how much cheese is consumed per person each year in the United States?
2. In making cheese, what is the product formed when bacteria digest the sugars in milk?
3. List the three basic steps involved in cheesemaking.
4. What is the pH of milk, and is it considered acidic, neutral, or basic?
5. How does the composition of cow's milk compare to that of hard cheddar cheese?
6. What type of bacteria are used in making mellow cheeses, like cheddar, Gouda, and Colby?

**Student Reading Comprehension Questions, cont.**

“Cheesy Science!” *ChemMatters*, December 2017/January 2018 Issue

1. Explain the process of how the casein micelles in hard cheeses coagulate.
2. What is the whey that is formed during cheesemaking?
3. How do different cheeses acquire their different tastes and textures?
4. What happens chemically as cheeses are aged?
5. What is the relationship between H+ and OH– (measured in mol/L) at a pH of 6?

## Answers to Student Reading Comprehension Questions

1. **On average, how much cheese is consumed per person each year in the United States?**

*The average cheese consumed per person in the United States is about 36 pounds per year.*

1. **In making cheese, what is the product formed when bacteria digest the sugars in milk?**

*In making cheese, when bacteria digest the sugars in milk, the product formed is lactic acid.*

1. **List the three basic steps involved in cheesemaking.**

*The three basic steps involved in cheesemaking are:*

* 1. *adding beneficial bacteria to milk,*
  2. *coagulating the milk into curd, and*
  3. *pressing and cutting the curd into cheese.*

1. **What is the pH of milk, and is it considered acidic, neutral, or basic?**

*The pH of milk is between 6.6 and 6.7 and, (since its pH is below 7, students should recognize that) it is considered acidic (even though it’s not stated as such in the article).*

1. **How does the composition of cow's milk compare to that of hard cheddar cheese?**

*When the composition of cow's milk is compared to hard cheddar cheese, the cow's milk has more water and carbohydrates and the cheese has more fat, protein, and minerals.*

1. **What type of bacteria is used to make mellow cheeses, like cheddar, Gouda, and Colby?**

*The type of bacteria used in making mellow cheeses is mesophilic bacteria.*

1. **Explain the process of how the casein micelles in hard cheeses coagulate.**

*In order for casein micelles in hard cheeses to coagulate, rennet is added to the mixture. The chymosin in the rennet removes the negatively charged ends from the micelle surfaces, reducing the micelles' polarity. The micelles are then repelled by water and begin to stick together and coagulate by forming long chains extending in all directions forming a 3-dimensional matrix.*

1. **What is the whey that is formed during cheesemaking?**

*Whey is the liquid by-product of cheesemaking, which contains soluble proteins. It is sometimes used as a substitute for skim milk, or as a fertilizer.*

1. **How do different cheeses acquire their different tastes and textures?**

*The different tastes and textures of cheeses are due to the different rates of acidification and the different culture organisms used in making the cheeses.*

1. **What happens chemically as cheeses are aged?**

*As cheeses are aged, the bacteria chemically break down the proteins first into peptides, then into amino acids, and then into amines; each succeeding step produces different, more complex flavors.*

1. **What is the relationship between H+ and OH– (measured in mol/L) at a pH of 6?**

*At a pH of 6, the H+ is 1 x 10-6 mol/L and the OH*– *is 1 x 10-8 mol/L.*

# Possible Student Misconceptions

1. **“Cheeses are high in fats and calories and should not be eaten if you are on a diet.”** *Cheeses are rich sources of proteins and minerals (including calcium). They are higher in fat content and calories than milk or other foods, but they can be eaten by individuals on diets. If the calories or fat content is an issue for an individual, some low fat cheeses are available that still supply the protein and minerals people need for a healthy lifestyle.*
2. **“Eating cheese can lead to heart diseases.”** *Evidence from international researchers discredits the misconception that eating cheeses and dairy products—even full fat versions—leads to heart diseases. This misconception is based on the fear of consuming high saturated fats in dairy products. While excessive saturated fats in the diet can be a problem for some individuals, health officials state that dairy products are an important part of a healthy diet. If people are still concerned, they can eat lower-fat varieties of dairy products like low-fat cheese or skim milk.*
3. **“Eating cheese can cause acne.”** *While there are many diets, theories, and anecdotes relating dairy and acne, studies show that there is not a clear link between the two. There are some studies that show an association between acne and consuming dairy products, but there is not a definitive cause and effect. The dairy sources of calcium and vitamin D needed for bone growth, and the protein for muscles are important for most people. When in doubt, consult with your doctor.*
4. **“Cheese is really just spoiled milk”** *In reality, cheese is made from the freshest milk that can be obtained. Spoiled milk may curdle and taste funny, but these are not characteristics desired in cheese. Making cheese from milk requires the strictest cleanliness and hygiene, in order to produce a consistent and edible product. In reality, cheese is preserved milk—it has the proteins, fats, minerals, and carbohydrates of milk concentrated into a longer lasting product that we call cheese!*

# Anticipating Student Questions

1. **“If people are lactose intolerant, can they eat cheese?”** *People who are lactose intolerant can eat hard, not soft, cheeses. The fermentation occurring in making hard cheeses converts almost all of the lactose into lactic acid, making it safe for lactose-intolerant people to enjoy them However, in soft cheeses, much less of the lactose has been fermented, so soft cheeses would not be a good choice.*
2. **“Is the lactic acid produced during fermentation in cheesemaking the same lactic acid that makes muscles sore when exercising?”** *Yes! Regardless of the source, lactic acid is always lactic acid. The lactic acid found in cheese is formed when the most common sugar in milk, lactose, is fermented by bacteria into lactic acid. The lactic acid (sometimes called lactate by athletes) formed in muscles is the product of anaerobically converting glucose (another sugar) for energy through glycolysis.*
3. **“Is the whey formed in making cheese related to the whey protein that many athletes take as a supplement?”** *Indeed, the whey found in protein supplements or whey powder is the same whey left over from making cheese. Whey is a watery material containing soluble proteins when the casein (cheese curds) are extracted. These proteins are extracted from the liquid whey, and concentrated and purified into the whey protein powder. Some whey protein products may add additional protein supplements from soy, egg, or other products.*
4. **“Can a person form a cheese addiction?”** *Some people have stated that cheese is like crack cocaine and is addictive. This is not true. Many people love cheese, but it is not addictive. Addictive eating behaviors are often associated with processed foods containing unusually high levels of fats or sugars such as pizza, chips, and cake. Part of the incorrect assumption that cheese can be addictive may be due to the casomorphins formed in the digestion of cheese binding to opioid receptors in the brain. However binding to a brain site and being addicted are not the same. So, you can safely eat and enjoy your cheese with no worries about addiction! (*[*https://www.sciencenews.org/blog/scicurious/no-cheese-not-just-crack*](https://www.sciencenews.org/blog/scicurious/no-cheese-not-just-crack)*)*
5. **“If I'm allergic to molds and penicillin, can I eat cheese?”** *The mold* Penicillium roqueforti *is used in blue cheeses like Roquefort. However, the enzymes in cheese break down most of the mold used in making the cheese. Typically, these cheeses are safe for most people to eat because the strain of Penicillium used in the antibiotic is* P. chrysogenum*. So, it is possible to be allergic to the antibiotic penicillin and still eat cheeses. When in doubt, however, consult your doctor.*
6. **“If I'm on a strict vegetarian diet, can I still eat cheeses if they’re made with rennet from cow stomach?”** *Strict vegetarians do not consume most animal products. Because rennet can be extracted from calf stomach (or goat or lamb stomachs), it may be an issue for some people. Much of the rennet used in making cheese today is produced genetically in bacteria and is not extracted from animal stomach, which may permit some vegetarians to eat cheeses. Many soft cheeses don't contain rennet but, because some do, consumers need to check the ingredients label or contact the company to be certain. If the rennet from bacteria is an issue for others, it is possible to purchase cheese made from enzymes extracted from plants like nettles. Also, making soft cheese (like cream cheese) at home would not involve rennet. Most certified-kosher cheeses are rennet-free; read labels and ask your grocers if you need vegetarian cheese.*
7. **"I see the terms rennet and rennin both used with cheesemaking. Are they the same thing?"** *No, they are not the same thing; however, rennet and rennin can be confusing. Rennet is a complex mixture of enzymes and other substances found in the gastric juice of many mammals' stomachs. Historically, rennet was extracted from cows' stomachs, but occasionally from goats or lambs, too. Rennin, which is another name for chymosin, is one of the enzymes found in rennet. It is an enzyme that precipitates the milk protein casein. Young mammals use rennin to coagulate casein so that it remains in their stomach longer for better digestion and absorption. So, rennin and rennet are related, but rennin is just one of the enzymes found in rennet.*

# Activities

**Labs and demos**

L**ab making mozzarella cheese:** Science Friday provides the lab, “Get Cheesy: Make Curds and Mozzarella”, which directs students to test how the composition of milks (from different animal or plant sources, or different fat contents of cow's milk) affects curd formation. Students continue the activity by making mozzarella cheese, and an extension allows students to redesign the experiment. (<https://www.sciencefriday.com/educational-resources/get-cheesy-make-curds-and-mozzarella/>)

**Lab precipitating and analyzing proteins from milk and soy milk:** "Proteins" from the Institute of Food Technologists' publication, *Food Chemistry Experiments* is a lab using an acid to precipitate casein (milk protein) from milk and making cottage cheese, which is then analyzed with a biuret test for proteins. Student directions, teacher tips, material lists, and sample student data are provided. (<http://www.ift.org/~/media/Knowledge%20Center/Learn%20Food%20Science/Experiments/TeacherGuidePROTEINS.pdf>)

**Media**

**Video of making cheese at home:** “Cheese Science: The 8 Steps of Cheese Making” (9:32) from the Utah Education Network provides this instructional video for making cheese in your kitchen. This video provides a nice visual, along with simple explanations of the process, and some of the chemistry involved in making the mozzarella cheese. (<https://www.youtube.com/watch?v=Qxr0w4P_tzw&feature=youtu.be>)

**Video lecture of micelle formation:** AK Lectures provides a video lecture, “Micelles and Lipid Bilayer” (13:22), with a diagram of micelles and with chemical terminology. The first part of the video (0:00–5:58) addresses micelles, while the latter portion concentrates on lipid bilayers and compares the two types of structures. (<https://www.youtube.com/watch?v=MTwUy3c5Etc>)

**Lessons and lesson plans**

**Lesson on studying properties of milk:** The National Agriculture in the Classroom Web site provides a lesson on milk, “Milk: The Scoop on Chemical and Physical Changes”. The two-part lesson aimed at grades 9–12 provides vocabulary review, background information, student directions and an infographic, suggested evaluations, and enrichment activities. (<https://www.agclassroom.org/teacher/matrix/lessonplan.cfm?lpid=246&author_state=0&grade=9&search_term_lp=cheese>)

**Making cheese lesson (with extension suggestions):** While this lesson, "Cheesy Chemistry", from PBS Learning Media is targeted for grades 6–8, the lesson is applicable to Gilbert’s "Cheesy Science" article, because it describes the chemistry of making cheese and suggests extended activities that high school students might use as a springboard for further work. This lesson includes a link to a background video, "Cheese: Not the Same Mold Story". ([https://aetn.pbslearningmedia.org/resource/sf10.sci.ps.psci.chmchng.lpcheese/cheesy-chemistry/#.Wd5dwZOWxhG](https://aetn.pbslearningmedia.org/resource/sf10.sci.ps.psci.chmchng.lpcheese/cheesy-chemistry/%23.Wd5dwZOWxhG))

**Projects and extension activities**

**Effects of different substrates and conditions on curd formation:** Students could design experiments to test numerous variables on the size, quality, and characteristics of cheese curds by changing the type of milk (cow, goat, soy) and both the pH and the rate of pH change of the milk, type of acid (lemon juice, vinegar, citric acid) used in curdling, agitation of the milk, and fat content of the cow milk (whole, 2%, skim) using protocol similar to "Cheese Production From Milk". (<http://terpconnect.umd.edu/~nsw/ench485/lab1.htm>) Tests for the curds could include size, texture, moisture content, odor, pH, and—if produced in a sanitary facility and approved by the teacher—the taste of the curds.

**Denaturing different proteins:** Casein in milk is denatured in making cheese and, in this home activity, the temperatures at which common proteins like casein (milk), albumin (egg), and keratin (hair) denature are compared. The activity could be extended by investigating the pH at which these proteins denature, or other methods of denaturation. (<https://www.education.com/science-fair/article/denaturing-proteins/>; note that this Web site requires a free registration for use.)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



***30* Years of *ChemMatters !***

Available Now!

This older article provides information on yogurt, a type of fermented fresh dairy product, which is produced by the acid precipitation of casein, rather than using rennet, as in cheesemaking. The article contains a figure showing the formation of casein strands from micelles, and a short discussion of lactose intolerance. (Evans, G. Yogurt. *ChemMatters*, 1989, *7* (3), pp 9–12)

While "Say Cheese" is an older article, it contains additional information to support the Gilbert article. This article includes comparisons of different cheese compositions, a diagram showing the chemical process of precipitating protein, and an activity to make lemon cheese. (Baxter, R. Say Cheese. *ChemMatters*, 1995, *13* (4), pp 4–7)

For a diagram and good explanation of micelles and polarity of molecules, readers can turn to "Demystifying Gross Stuff". The section of the article concerned with sebum, which causes acne, includes the sections on micelles and polar molecules and their behavior. (Rohrig, B. Demystifying Gross Stuff. *ChemMatters*, 2011, *29* (3), pp 12–14)

"Who Put the Cheddar in Cheese?" provides additional information on cheesemaking, explaining the composition of milk, the colloidal nature of milk, and showing numerous pictures of the process of making cheese. (De Antonis, K. Who Put the Cheddar in Cheese? *ChemMatters*, 2012, *30* (1), pp 12–13)

The February 2012 Teacher's Guide for "Who Put the Cheddar in Cheese?" (above) includes additional information on the history of cheese, rennet, the chemistry or rumination, and lactobacilli. In-class activities include making fresh cheese, making yogurt, a milk analysis, and making cheddar cheese curds.

"Not Milk? Living with Lactose Intolerance" explains the problems some people have digesting the primary sugar in milk and other dairy products, lactose. Chemical structures of lactose, maltose, and sucrose are compared and suggestions for lactose-free foods are discussed. (Rohrig, B. Not Milk? Living with Lactose Intolerance. *ChemMatters*, 2013, *31* (2), pp 18–19)

The April 2013 Teacher's Guide for "Not Milk? Living with Lactose Intolerance" (above) adds information on lactose, including ways to modify or eliminate it in dairy products, and more background information on lactose and lactase.

The whey left over from producing cheese may be modified and used as whey powder protein. This article discusses the pros and cons of using sports supplements like whey, and it includes a sidebar explaining three types of whey protein powders. (De Antonis, K. Sports Supplements: Helpful or Harmful? *ChemMatters*, 2013, *31* (3), pp 12–14)

The October 2013 Teacher's Guide for "Sports Supplements: Helpful or Harmful" includes extensive material on whey protein powder, including sources, composition, and possible health effects.

For information on fermented foods (cheese is a fermented food) including yogurt, sauerkraut, pickles, kimchee, kombucha, cottage cheese, and buttermilk that contain probiotics with beneficial bacteria, see this article, "Probiotics: Good Bacteria, Good Health". (Haines, G. Probiotics: Good Bacteria, Good Health. *ChemMatters*, 2015, *33* (3), pp 11–13)

A brief discussion of yogurt and *Lactobacillus* bacteria associated with fermenting milk is found in the October 2015 Teacher's Guide for "Probiotics: Good Bacteria, Good Health" (above).

"Kombucha: Something's Brewing" devotes the entire article to this fermented food, which is viewed as a probiotic. The author explains beneficial bacteria and fermentation (which also occurs in making cheese). (Nolte, B. Kombucha: Something's Brewing. *ChemMatters*, 2016, *34* (1), pp 14–15)

The February 2016 Teacher's Guide for "Kombucha: Something's Brewing" (above) adds information on fermentation and types of fermented foods, lactic acid fermentation, and fermentation in ruminant animals.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

This article identifies bitter compounds found in cheeses, from fermentation and other sources, and the compounds found in cheese that mask the bitterness, making them palatable for humans. The cheeses analyzed are Baraka, brie, Gouda, and ricotta. (Homma, R., et al. Identification of Bitterness-Masking Compounds from Cheese. *J. Agric. Food Chem.*, 2012, *60* (18), pp 4492–4499; <http://pubs.acs.org/doi/pdf/10.1021/jf300563n>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

For a thorough explanation of rennet coagulation in milk and how it relates to cheesemaking and whey production, readers can access "Rennet Coagulation and Cheesemaking Properties of Thermally Processed Milk: Overview and Recent Developments". (Kethireddipalli, P.; Hill, A. Rennet Coagulation and Cheesemaking Properties of Thermally Processed Milk: Overview and Recent Developments. *J. Agric. Food Chem.*, 2015, *66* (43), pp 9389–9403; <http://pubs.acs.org/doi/abs/10.1021/jf504167v?src=recsys&journalCode=jafcau>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

*The Science of Cheese* is a book for nonscientific readers that provides in-depth information on the biology, chemistry, and physics of all things related to cheese. It includes history, laws, and possible activities to conduct at home. (Tunick, M. *The Science of Cheese*; Oxford University Press: New York, NY, 2013.

# Web Sites for Additional Information

**History of cheese**

The Web site *Today I Found Out* provides "The History of Cheese", starting with a likely Arab journeying across the desert. This short, readable site is a good start for understanding cheese. (<http://www.todayifoundout.com/index.php/2013/04/the-history-of-cheese/>)

The National Historic Cheesemaking Center (in Wisconsin, of course) also explains the "History of Cheese", with an emphasis on the U.S. and Wisconsin in its explanation. (<http://www.nationalhistoriccheesemakingcenter.org/history-of-cheese/>)

**Facts about milk and cheese**

The *Milk Facts* Web site has an extensive array of links to specific aspects of dairy products, and "Cheese Production" is only a portion of the information available. There are also links to "Milk Composition", "Nutrition", "Microbiology", "Processing", and "Resources" that provide more information, as well as links on "Fluid Milk Production", "Ice Cream Production", "Yogurt Production", and 'Cheese Production". (<http://www.milkfacts.info/Milk%20Processing/Cheese%20Production.htm>)

"The Chemistry of Milk" contains extensive information on milk, with basic chemistry and biology concepts highlighted and explained. This resource from the *Dairy Processing Handbook* Web site has figures, illustrations, and a thorough discussion of all things related to milk. (<http://dairyprocessinghandbook.com/chapter/chemistry-milk>. Note that readers must sign in with an email address.)

**Rennet**

"You Can Thank Genetic Engineering for Your Delicious Cheese" on the *Gizmodo* Web site explains how rennet is used in making cheese. The transition from rennet, obtained from veal through the 1970s, to genetically engineered rennet in the 1990s is an interesting story. [(https://www.gizmodo.com.au/2016/05/you-can-thank-genetic-engineering-for-your-delicious-cheese/](file:///C:\Users\Bill\AppData\Local\Packages\Microsoft.MicrosoftEdge_8wekyb3d8bbwe\TempState\Downloads\(https:\www.gizmodo.com.au\2016\05\you-can-thank-genetic-engineering-for-your-delicious-cheese\))

"Cheese Science" provides an explanation of cheesemaking, including a detailed discussion (with diagrams) of the rennet coagulation of milk. *The CheeseScience.net* site also has a few links to other cheese resources, including information on cheddar and an introduction to cheese science. (<http://www.cheesescience.net/2008/06/rennet-coagulation-of-milk.html>)

**The difference between rennet and rennin**

The Web site “Sciencing” provides a quick explanation of the difference between rennet and rennin at <https://sciencing.com/difference-between-rennin-rennet-8182538.html>.

**Casein**

The *Milk Facts* Web site provides "Milk Proteins" and explains the properties of the milk protein, casein. The site includes sections on properties, chemistry, deterioration, and effect of heat on milk proteins—primarily casein. (<http://www.milkfacts.info/Milk%20Composition/Protein.htm>)

The *Danisco* Web site includes "Dairy Chemistry—Part I of IV: Casein", with a table comparing casein and whey protein, and a second table illustrating the causes for casein aggregation into micelles. An explanation of casein is included on the site. (<http://www.danisco.com/food-beverages/dairy/insights-for-cultured-dairy-newsletter/april-2016/dairy-chemistry-part-i-of-iv-casein/>)

**Micelles**

An introductory explanation from the University Federico II of Naples, Italy, explains micelles and their formation, with helpful diagrams. This Web page is short, colorful, and clear in its information. (<http://www.whatischemistry.unina.it/en/micella.html>)

The *Cheese Science* Web site "Coagulation—Curds Getting Comfy" provides information on the formation of micelles in cheesemaking. There are useful diagrams and explanations of the hydrophobic and hydrophilic forces involved in micelle formation. (<http://www.cheesescience.com/2011/07/29/coagulation-getting-comfy-with-your-curds/>)

**Whey**

"Whey Processing" on the *Dairy Processing Handbook* Web site is an in-depth look at whey: processing, uses, composition, and much more. Numerous tables of data are provided, along with diagrams of equipment and flowcharts. (<http://dairyprocessinghandbook.com/chapter/whey-processing>. Note that readers must sign in with an email address.)

"What is Whey Protein?" from *Live Science* explains how whey is derived (from cheesemaking), and its use as a protein supplement for athletes and active people. The site includes a section on the safety and effectiveness of whey protein supplements. (<https://www.livescience.com/45120-whey-protein-supplements.html>)

**Cheeses and pH**

A 2002 publication, *Dairy Pipeline*, from the Wisconsin Center for Dairy Research has a cover article, "Cheese pH—What's Behind the Rise and Fall" that discusses pH, buffers, measuring pH in cheese, and much more. The publication also has an article on "Salt Crystal Size and Salt Retention in Cheddar Cheese". (<https://www.cdr.wisc.edu/sites/default/files/pipelines/2002/pipeline_2002_vol14_04.pdf>)

A short, general review of the pH concept and its applications to cheese, from the University of Guelph, is located at <https://www.uoguelph.ca/foodscience/book-page/ph-0>

**Types of cheeses**

It is estimated that there are over 2,000 different cheeses. This art infographic looking like a cheese wheel lists 66 cheeses and groups them into milk source and types (hard, semi-hard, and soft), and it includes a representation of a slice of each type. (<http://thumbnails.visually.netdna-cdn.com/the-charted-cheese-wheel_51ae17314abed.jpg>)

*Men's Journal* provides "Name That Cheese: 35 Types to Try", which includes information for each type, including appearance, texture, flavor, aroma, what to buy, and a picture of each type. (<http://www.mensjournal.com/food-drink/collections/35-types-of-cheese-everyone-should-know-w203742>)

**Mesophilic and thermophilic cheese bacteria**

For an exhaustive treatment of the bacterial cultures used in cheesemaking, including sections about starter bacteria, lactic acid bacteria; bacteria classification based on temperatures; classification based on fermentation; cultures used for specific cheeses; artisanal cheese cultures; salt sensitivity; and much more, see <http://www.innocua.net/web/download-2290/cm-0004-12.pdf>.

**Cheese made with stinging nettles instead of rennet**

The *International Journal of Gastronomy and Food Science* provides information on making cheese without the use of the animal component, rennet. "Nettle Cheese: Using Nettle Leaves (*Urtica dioica*) To Coagulate Milk in the Fresh Cheese Making Process" explains how the stinging nettle plant can be used as a vegetable coagulation substitute for rennet. (<http://www.sciencedirect.com/science/article/pii/S1878450X16300178>)

**Natural versus processed cheeses**

The U.S Environmental Protection Agency supplies the publication "Natural and Processed Cheese" to explain the processes and differences in making natural and processed cheeses. Tables, flowcharts, and clear explanations provide readers with accurate information. (<https://www3.epa.gov/ttn/chief/ap42/ch09/final/c9s06-1.pdf>)

**Dairy consumption and heart disease**

The U.S. National Institutes of Health Web site provides information for people concerned about the consumption of dairy products and links to heart diseases in the 2014 report, "Dairy and Cardiovascular Disease: A Review of Recent Observational Research". In short, 18 studies were reviewed, and the results indicate that dairy consumption does not contribute to cardiovascular disease; readers can read the whole article at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4006120/>.

# About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.



**Teacher's Guide for**

### *“Drained: The Search for Long Lasting Batteries”*

**December 2017/January 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Reaction rates** | During a unit on reaction rates or kinetics, teachers can use the redox reaction inside the lithium-ion battery as an example of the way temperature affects the rate of reactions. |
| **Oxidation/Reduction reactions** | The half-reactions that occur at the anode and cathode of the lithium ion battery can be part of a lesson on oxidation/reduction reactions, as can the reaction in Volta’s original experiment. |
| **Electrochemistry** | The lithium-ion battery can be used as an example of an electrochemical reaction—using chemicals to produce electricity—complete with the activity series, EMF calculations, and cell potentials. The more commonly used example of the voltaic pile from this article can also be used. |
| **Electrochemical cells** | A discussion of the Li-ion battery (or batteries in general) can lead to differentiating between cells and batteries (e.g., 1.5-V dry cells vs 9-V batteries). |
| **Reversible reactions** | When teaching about reversible reactions in equilibrium, teachers can use the oxidation/reduction reactions occurring in the discharging and charging of a lithium-ion battery as a prime example. |
| **Ions** | The ions in the battery electrolyte, as well as in the anode and cathode, demonstrate the importance of the ionic state of many elements in chemical reactions. |
| **Nanotechnology** | The two current research projects utilizing nanotechnology described in the article: the silicon nanowires proposed for use as the anode in place of carbon in one project, and the use of bundles of gold nanowires as the cathode in another are examples that can be used to highlight the progress of nanotechnology in chemistry. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:

**ELA-Literacy.RST.9-10.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**ELA-Literacy.RST.9-10.5.** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, and energy).

**ELA-Literacy.RST.11-12.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

**ELA-Literacy.RST.11-12.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

* Links to **Common Core Standards for Writing**:

**ELA-Literacy.WHST.9-10.2F.** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

**ELA-Literacy.WHST.11-12.1E.** Provide a concluding statement or section that follows from or supports the argument presented.

* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:

**ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.

**ELA-Literacy.WHST.11-12.1.A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

* Links to **Next Generation Science Standards**:

**HS-PS1-5**: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

**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:**
* LS1.A: Structure and Function
* **Crosscutting Concepts:**
* Cause and effect: Mechanism and explanation
* Structure and function
* Stability and change
* **Science and Engineering Practices:**
* Constructing explanations and designing solutions
* Obtaining, evaluating, and communicating information
* **Nature of Science:**
* Scientific knowledge is based on empirical evidence

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the December 2017/January 2018 issue:

* Metric units
* Structural Formulas
* Fermentation
* pH
* Electrochemistry
* Oxidation & Reduction
* Amines
* Allotropes
* Physical properties
* London dispersion forces

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p.54):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

As an alternative to using the Anticipation Guide for this article, consider this idea to engage your students in reading.

* Ask students to list ways they can make the batteries in their cell phones last longer.
* After students have made their lists, they should read the article and compare their original thoughts to the information in the article.
* **Graphic Organizer (p. 55):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers 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 |

* **Student Reading Comprehension Questions (p. 56-57):** The Student Reading Comprehension Questions are designed: to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.
* Most of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make decisions in their personal lives.
* The infographic on page 19 provides more information to support the article “Drained: The Search for Long Lasting Batteries” on pages 10-12.
  + You could ask students what batteries and pencils have in common (graphite), then ask them to elaborate on the physical properties of graphite that makes it appropriate for both uses.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.

“Drained: The Search for Long Lasting Batteries” *ChemMatters*, December 2017/January 2018 Issue

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

“A Close-up Look at the Quality of Indoor Air” (*ChemMatters*, April/May 2016 Issue)

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. 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 easiest way to improve your phone’s battery life is to stop turning on your phone’s screen to check for notifications. |
|  |  | 1. Sending data requires about the same amount of power to transmit as talking on your phone. |
|  |  | 1. You should let your battery discharge almost all of the way between charges. |
|  |  | 1. Today’s batteries and the original batteries all have the same components: an anode, a cathode, and an electrolyte. |
|  |  | 1. The solvent in a lithium ion battery is water. |
|  |  | 1. If two different metals are connected by an electrolyte solution, an electric potential is created. |
|  |  | 1. Batteries have been greatly improved to keep up with their use in electronics. |
|  |  | 1. The first battery was produced in 1800. |
|  |  | 1. Carbon atoms and silicon atoms can hold onto the same number of lithium ions. |
|  |  | 1. The iPhone’s battery operates best between 0°C and 35°C. |

## Graphic Organizer

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

“Drained: The Search for Long Lasting Batteries” *ChemMatters*, December 2017/January 2018 Issue

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

.

|  |  |  |  |
| --- | --- | --- | --- |
| ***Battery Part*** | ***Anode*** | ***Cathode*** | ***Electrolyte*** |
| **What it does/ What happens** |  |  |  |
| **Single use alkaline battery** |  |  |  |
| **Lithium-ion rechargeable battery** |  |  |  |
| **Future possibilities being researched** |  |  |  |

**Summary:** On the back of this paper, list two ways to increase the battery life of current cell phone batteries, and why these methods work.

## Student Reading Comprehension Questions

“Drained: The Search for Long Lasting Batteries” *ChemMatters*, December 2017/January 2018 Issue

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

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

1. What is the dominant type of rechargeable battery used for electronics?
2. How are temperature and battery life related?
3. What are the three components of a battery?
4. Describe the reactions that take place in common, single-use alkaline batteries.
5. What are the most common materials used in making a lithium-ion battery?
6. Why isn’t water a good material to use as the solvent for the electrolyte of the lithium-ion battery?

**Student Reading Comprehension Questions, cont.**

“Drained: The Search for Long Lasting Batteries” *ChemMatters*, December 2017/January 2018 Issue

1. How did Alessandro Volta make the first battery, and how did it work?
2. Identify and describe the reactions that occur to power a cell phone.
3. Give the equations for (a) the oxidation reaction, and (b) the reduction reaction that occur in a lithium-ion battery.
4. What was the major problem with using silicon in place of carbon in a lithium battery?   
   How was it overcome?
5. What are the two problems with using liquid electrolytes in lithium batteries?
6. Describe two recent innovations in the development of lithium batteries.

## Answers to Student Reading Comprehension Questions

1. **What is the dominant type of rechargeable battery used for electronics?**

*The dominant type of rechargeable battery used for electronics is the lithium-ion battery.*

1. **How are temperature and battery life related?**

*Temperature and battery life are related, because the chemical reactions that power the battery speed up as temperature rises, shortening battery life. If the battery is kept cool, the reactions slow down and the life of the battery is extended.*

1. **What are the three components of a battery?**

*The three components of a battery are*

1. *the anode, or negative end;*
2. *the cathode, or positive end; and*
3. *the electrolyte, the ion transporter.*
4. **Describe the reactions that take place in common, single-use alkaline batteries.**

*In single-use alkaline batteries,*

1. *the zinc metal of the anode is oxidized to Zn2+ ions, while*
2. *the manganese(IV) oxide (MnO2) of the cathode is reduced to manganese(II) oxide (MnO), or manganese(III) oxide (Mn2O3), depending on the type of electrolyte.*
3. **What are the most common materials used in making a lithium-ion battery?**

*The most common materials used in making a lithium-ion battery are lithium cobalt oxide (LiCoO2) for the cathode; graphite (C6) for the anode; and a combination of lithium salts, such as LiPF6, LiBF4, or LiClO4 for the electrolyte.*

1. **Why isn’t water a good material to use as the solvent for the electrolyte of the lithium-ion battery?**

*Water is not a good solvent because it reacts vigorously with alkali metals.*

1. **How did Alessandro Volta make the first battery, and how did it work?**

*To make the first battery, Alessandro Volta “stacked alternating discs of zinc and copper separated by wet paper soaked in salt, which served as the electrolyte. This device created a physical link between two metals through which electrons could be exchanged to create an electrochemical potential. When wires connecting the top and the bottom of the pile were brought together, they made a spark.”*

1. **Identify and describe the reactions that occur to power a cell phone.**

*An oxidation reaction takes place when an electron is released from the graphite anode; a lithium ion moves from between the graphite through the Li+-permeable membrane, into the cathode. The released electron travels through the external circuit and powers the phone. In a reduction reaction, the electron returns to the cathode to allow for LiCoO2 production and completes the circuit.*

1. **Give the equations for (a) the oxidation reaction and (b) the reduction reaction that occur in a lithium battery.**
2. *Oxidation/Anode: LiC6* 🡪 *Li+ + C6 + e–*
3. *Reduction/Cathode: CoO2 + Li+  + e–* 🡪 *LiCoO2*
4. **What was the major problem with using silicon in place of carbon in a lithium-ion battery? How was it overcome?**

*The problem with using silicon in lithium-ion batteries is that silicon swells as it absorbs lithium ions and then shrinks when the ions are pulled out of the silicon. This swelling and shrinking causes the silicon to fracture after only a few cycles, ruining the battery. To overcome this issue, researchers “developed a silicon nanowire electrode that leaves room for thin ‘hairs’ of silicon to swell and shrink as they absorb or release Li+. The unique geometry allows the battery to cycle without damaging the silicon—and unlocks the energy density benefits of using silicon instead of carbon.”*

1. **What are the two problems with using liquid electrolytes in lithium batteries?**

*The problems with using liquid electrolytes in lithium batteries are:*

1. *the liquid restricts how fast lithium ions can flow, and*
2. *the liquids also limit the temperature range over which the battery can function.*
3. **Describe two recent innovations in the development of lithium batteries.**

*The article describes three innovations. Students could use any two of the following three.*

1. *Yi Cui of Stanford, worked to make silicon a viable replacement for carbon in the lithium battery, since each silicon atom can hold onto four lithium ions instead of one lithium ion per carbon atom. Since silicon expands and shrinks in the process it has a tendency to fracture after a few cycles. Cui’s team developed a silicon nanowire electrode that leaves room for thin hairs of silicon to swell and shrink as they absorb or release lithium ions.*
2. *Mya Le Thai, a graduate student at the University of California, Irvine, used bundles of gold nanowire, coated with manganese(IV) oxide to help hold the charge, and a Plexiglas-like gel to prevent corrosion, to make the cathode of the battery. The nanowires provide more surface area in a smaller volume. This new cathode fully charges and discharges up to 200,000 times without damaging the metal, compared to the 5,000 to 7,000 charges a lithium-ion battery can withstand before dying.*
3. *Yuki Kato and Ryoji Kanno, in collaboration with Toyota, have created different crystalline structures that include atoms of lithium, silicon, phosphorus, sulfur, and carbon though which ions could flow faster than the traditional liquid electrolyte currently in use. The crystalline electrolyte holds more charge, charges faster, and increases the safe operating temperature range of the battery.*

# Possible Student Misconceptions

1. **“Batteries should be recharged when the charge drops below 20%, and they should be charged to 100%.”** *Lithium-ion batteries can be charged at any state of charge without harming the battery. They can be charged to 100% and kept on the charger without damaging the battery. Cell phones are equipped with a sensor that reduces the current to the battery when it approaches full charge. However, it is best for the battery if the charge stays between 30% –80% charge. Previous rechargeable batteries may have had restrictions about when to charge them, but lithium-ion batteries do not. However, periodically letting the battery charge fall below 10% before recharging it does help maintain the digital power gauge inside the phone. This gauge sets the range of charge from   
   0–100%. When the battery is kept above 30% this gauge develops memory and begins to detect 70% charge as full charge, thus decreasing the charge capacity of the battery. Letting the battery run down to 10% and charging to 100% helps keep the range of the gauge true.*
2. **“Electrons can flow through an electrolyte solution.”** *In an electrochemical cell the conduction of electricity through an electrolyte solution does not involve the electrons themselves passing through the solution. Electrons move only through the wires that connect the anode and cathode. Ions formed at either electrode create a charge imbalance in the electrochemical cell, which is alleviated by ions already in the electrolyte solution moving to either the anode or the cathode until the charge equilibrium of the solution is restored.*
3. **“Storing batteries in the freezer extends their life.”** *Storing lithium-ion batteries in the freezer can cause the liquid electrolyte in the batteries to expand and change the shape of the housing. Also, moisture in the freezer can contaminate the battery and possibly lead to the battery becoming short-circuited. While it is true that cooler temperatures slow down the secondary chemical reactions within the battery, the freezer is not a good place to store batteries. You can however store the batteries in the refrigerator. The batteries should be stored with 30–50% state of charge in an airtight container along with a packet of desiccant.*
4. **“Lithium batteries have memory and this will affect how they charge.”** *Memory effect is something that was observed in Ni-Cd rechargeable batteries. In Ni-Cd batteries, if the batteries are consistently recharged before they fully discharge, the battery develops a memory for the amount of charge used to recharge the battery and over time operates to that capacity rather than full capacity. To alleviate this problem the batteries must be almost fully discharged before they are recharged. Lithium batteries do not exhibit this memory effect or voltage depression. Therefore, you can recharge the battery whenever you want to, no matter what level of charge it has. You can even charge the battery while using the phone without harming the battery. While the lithium-ion battery itself does not have memory, frequent partial discharges create a condition called digital memory in the device’s power gauge. To recalibrate the power gauge, let the battery discharge to 5%–10% and then recharge.*
5. **“Turning off your phone can damage the battery.”** *Turning off your phone does not damage the battery. You can turn the phone completely off—and even remove the battery—without any fear of harming the battery. In fact, sometimes a simple reboot can actually help restore battery functionality*
6. **“Using the internet will run down the battery faster than anything else.”** *Actually, it is the screen being on that drains the battery the most. You can turn the brightness of the screen down to reduce its use of battery, but it is still a battery hog. Activities that are graphic-intensive, like on-line gaming or watching YouTube videos, deplete the battery more than any other type of activity.*
7. **“A battery does not lose charge unless it is used.”** W*hether it is being used or is turned off, a battery will continue to lose charge***.** *The lifespan of a lithium-ion battery is limited by the manufacture date. It starts losing life the minute it leaves the production line at the factory. The battery will slowly discharge over time until it loses all of its electrochemical potential. When you purchase a cell phone battery ask for one with the most recent date. While turning a device off conserves the battery, it does not completely stop the battery from discharging.*

# Anticipating Student Questions

1. **“Why is lithium the element chosen for use in cell phone batteries?”** *At 6.94 g/mol, lithium is the lightest of all the metals. Whether it is used for a cell phone or a car, the lighter the weight of the battery, the better. Also, the lithium half-cell has one of the greatest electrochemical potentials at 3.05 volts, resulting in high energy density and a higher power-to-mass ratio for this element. Lithium is relatively high on the activity series of metals, meaning that lithium atoms will easily oxidize to its cation in a chemical reaction, providing a ready source of electrons. These are the chemistry reasons lithium is so attractive for use in batteries. Economically, lithium is relatively inexpensive and is easy to obtain from brine solutions created at mining sites.*
2. **“Why does my cell phone turn itself off if I leave it in the sun?”** *Cell phones are equipped with several safety devices, one of which is an internal temperature sensor. When the sensor detects temperatures higher than a preprogrammed set value, it turns the phone off in order to protect the battery from thermal runaway. Thermal runaway is a chain reaction that can quickly lead to the battery exploding. Even with the phone shut down, the electrolyte still may heat up to its boiling point, increasing the internal pressure of the battery to the point that it explodes. Some batteries are equipped with vent holes so gas can escape without damaging the battery casing. However, these cannot accommodate rapid increases in pressure caused by boiling electrolyte.*
3. **“What was happening that caused the new Samsung phones to explode?”** *After much research, Samsung found that the flaw in the Samsung Galaxy Note 7 phones that was causing some phones to explode was not in the electronics or programming of the phone, but in a problem with the batteries. In the race to make a battery smaller and more efficient, some of the Samsung batteries were too cramped in their housing, which caused the two electrodes to touch. In the second batch of batteries that were made for the phone by a different manufacturer, the electrode separators were flawed. In some batteries the separators were punctured, while in others layers of insulating separators were missing. In both sets of batteries, the flaws led to the anode and cathode coming into direct contact. This causes the battery to short-circuit and experience what is known as thermal runaway. Thermal runaway happens when heat that is generated by rapid charging or discharging causes the electrolyte in the battery to react with other chemicals, creating a gas which releases more heat at a faster rate, in what becomes an uncontrolled feedback loop. An explanation with video can be found at these two sites:* <https://www.cnet.com/news/samsung-answers-burning-note-7-questions-vows-better-batteries/> *or* <https://www.theverge.com/2016/9/8/12841342/why-do-phone-batteries-explode-samsung-galaxy-note-7>*.*
4. **“Is the voltage produced by the lithium-ion battery the highest voltage chemists can produce in an electrochemical cell?”** *No, there are other chemical combinations of anode and cathode materials that can result in higher voltage. One of the highest voltages would come from a reaction involving the reduction of fluorine atoms in acidic solution to produce hydrogen fluoride, and the oxidation of lithium atoms to their ions, according to the following half-reactions.*

F2 (g) + 2 H+ + 2 e– 🡪 2 HF(aq) Eo = + 3.03 V

2 Li(s) 🡪 2 Li+ + 2 e– Eo = + 3.05 V

F2(g) + 2H+(aq) + 2 Li(s) 🡪 2 HF(aq) + 2 Li+(aq) Eo = + 6.08 V

*While this reaction may generate more voltage, the safety concerns and difficulty in working with the materials involved—fluorine gas especially— would hinder using this reaction in batteries*. *To get higher voltages, single electrochemical cells are connected in series with one another. An example is the 9-V battery. If you carefully cut the casing away from the battery, you find six 1.5-V cells connected together inside.*

1. **“I see the term ‘dry cell battery’ used sometimes. What do they mean by that?”** *Actually, to the chemist, the terms cell and battery are different things. A cell is a single electrochemical unit producing a given amount of electrical energy, or voltage, while a battery indicates that several cells have been joined together to produce a collective higher voltage. Most of the “batteries” we use to power flashlights and small battery-operated devices are single cells. Whether it is a D cell, C cell, AA, or AAA “battery”, they all produce the same voltage—1.5 volts. The 9-V battery is a true battery. It is the combination of six 1.5-V cells connected in series to produce 9-V of potential energy.*

*The term “dry” refers to the electrolyte used in the cell. In a dry cell, the electrolyte is in the form of a paste with only enough liquid to allow ion—and thus—current flow. In a typical alkaline battery, the electrolyte is a paste of ammonium chloride, NH4Cl. In a wet cell, the electrolyte is liquid and the battery will need to be kept in an upright position to prevent the liquid from leaking out. The battery in a car uses wet-cell technology, while batteries used in portable electronics use dry cell technology.*

# Activities

**Labs and demos**

**Making a two-cell battery:** Students make their own two-cell battery with aluminum and copper electrodes immersed in an electrolyte solution, changing the electrolyte solution as they try to determine which electrolyte solution is best suited for making batteries. The procedure is well illustrated. (<https://www.teachengineering.org/activities/view/cub_electricity_lesson03_activity2>)

**Making and evaluating electrochemical cells and batteries:** After a brief introduction to the history of batteries, students prepare five different types of electrochemical cells—“Voltaic Pile”, “Electrochemical Cell”, “Lemon Cell”, “Storage Cell”, and “Dry Cell”. Students measure the output and evaluate the usefulness of each type of cell. (<http://www.chymist.com/batteries.pdf>)

**Simulations**

**Electrochemical cell voltmeter:** The students prepare virtual cells with different electrodes and electrolyte concentrations and measure their voltages. Increasing levels of difficulty are provided, which call on the student to calculate the voltage and enter the answer. (<http://web.mst.edu/~gbert/Electro/Electrochem.html>)

**“Voltaic Cell Virtual Lab”:** This electrochemical cell simulator gives students four choices for each anode and cathode, as well as four electrolyte options. After designing the cell, students virtually measure the voltage. (<http://www.kentchemistry.com/moviesfiles/Units/Redox/voltaiccelll20.htm>)

**Media**

**Recent developments with lithium-ion batteries:** An interview (6:51) with Helena Braga, the co-developer of the glass lithium-ion battery, provides an opportunity for students to see and hear from a scientist currently working on battery technology. The video explains the dangers of exploding Li-ion batteries, and animated explanations compare how lithium-ion batteries and glass lithium-ion batteries operate. (<https://www.youtube.com/watch?v=wl0I2vl6ul0>)

**Lithium mining and purification for use in batteries**: This short video (7:21) shows students how lithium is mined and extracted for use in the lithium-ion battery. (<https://www.youtube.com/watch?v=Lt6oKRQqoSc>)

**Use of computer modeling to design better batteries:** This video (7:47) contains information about using computer simulation of molecular modeling and chemical experimentation to determine optimal combinations of components for future lithium batteries.

(<https://www.youtube.com/watch?v=8iT9B7aJNKc>)

**Lessons and lesson plans**

**“Electrical Energy Storage” in batteries and voltaic piles:** Part one of this 65-minute lesson contains a lecture about how electrical energy is stored and how a battery works. Part two concerns the voltaic pile and provides students the opportunity to experiment with a voltaic pile made with pennies, nickels, and wet paper towel squares soaked in water or lemon juice. (<http://www.uwyo.edu/scienceposse/resources/lesson-plans/former-fellow-lesson-plans/luke-dosiek/luke-diosiek-fun-with-electricity-electrical-energy-storage.pdf>)

**“Voltaic Cells”:** In this one class-period lesson, students use information from a PowerPoint presentation to learn about voltaic cells and how to calculate cell potential. Students use a provided flowsheet to label the movement of ions in a voltaic cell, and then they conduct an open inquiry to create a cell with the highest energy output. (<http://www.cpalms.org/Public/PreviewResourceLesson/Preview/156833>)

**Projects and extension activities**

**Environmentally focused lessons about batteries:** Sponsored by the Rechargeable Battery Recycling Corporation and National Geographic, these lessons and activities focus on renewable energy and recycling. Instructions for five activities are included, along with excellent diagrams and a historical timeline of “Electricity and Batteries” beginning in 600 B.C. through 2001. (<http://www.panasonic.com/environmental/rbrc_lesson_plan.pdf>)

**Research latest developments in battery technology:** Students can be assigned one of the new developments in lithium-ion battery technology to research and prepare a poster presentation to the class. Some ideas they can research are batteries that use graphene as the carbon anode, batteries that use glass as the separator, batteries that use water as the electrolyte, or batteries that use sulfur. Some topics can be found at these Web sites: <https://www.sciencedaily.com/news/matter_energy/batteries/> or <https://en.wikipedia.org/wiki/Research_in_lithium-ion_batteries>.

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



***30* Years of *ChemMatters !***

Available Now!

In the April 2011 *ChemMatters* article “Did You Know?” author Pages describes how a lithium-air battery works, compared to a lithium-ion battery. Scientists studying new types of batteries are looking at lithium-air batteries as an option for future cars. (Pages, P. Electrochemistry: Making Better Electric Cars. *ChemMatters*, 2011, *29* (2), p 4)

A discussion of the environmental impact of lithium batteries includes information about where and how lithium is mined, as well as how lithium batteries work, compared to other batteries. A diagram of a lithium battery illustrates the charging process. (Goode, R. & Sitzman, B. Lithium-ion Batteries: A Clean Source of Energy. *ChemMatters*, 2011, *29* (3), p 5)

Author Tinnesand provides an article about electric cars that contains a diagram of a car’s lithium-ion battery, compared with a diagram of a typical lead-acid battery. He explains the benefits of using lithium compared to lead in batteries used for electric cars. (Tinnesand, M. Drivers Start Your (Electric) Engines. *ChemMatters*, 2013, *31* (1), pp.14–16)

The Teacher’s Guide for the February, 2013 *ChemMatters* article above contains additional information about lithium resources and how they are mined. The guide also elaborates on why lithium is suited for use in batteries.

# Web Sites for Additional Information

**Lithium-ion batteries**

A good Web site for students to explore how lithium-ion batteries work can be found at Explain that Stuff. Animated gifs simulate how a lithium-ion battery works, while thorough explanations give students more information about the different components of these batteries. (<http://www.explainthatstuff.com/how-lithium-ion-batteries-work.html>)

Battery University has a plethora of information on all types of batteries. The “courses” are listed in the left-hand corner, with the courses specific to lithium-ion batteries numbered BU-204–208, BU-304–310, and BU-409–410. (<http://batteryuniversity.com/learn/article/lithium_based_batteries>)

**Samsung cell phone explosions**

In “Samsung Galaxy Note 7 recall: Here’s what happens now”, a short video (2:31) accompanied by illustrated explanations details why the Note 7s had problems with their lithium-ion batteries and what steps Samsung took to prevent future problems. (<https://www.cnet.com/news/samsung-galaxy-note-7-return-exchange-faq/>)

“The Science Behind Exploding Phone Batteries” explains how the lithium-ion battery works and what went wrong with the Samsung Galaxy Note 7. A short video (3:41) accompanies the explanation. (<https://www.theverge.com/2016/9/8/12841342/why-do-phone-batteries-explode-samsung-galaxy-note-7>)

**Lithium-ion battery care**

Knowing the best practices when it comes to caring for a lithium-ion battery can help ensure the battery will see its full life. “How to Charge and When to Charge” from Battery University answers several questions about battery maintenance. (<http://batteryuniversity.com/learn/article/how_to_charge_when_to_charge_table>)

“8 Essential Tips to Keep Your Phone’s Battery Healthy” is the title of the *Popular Mechanics* article that tells what a battery is made of, how it works, and how to keep it working well. (<http://www.popularmechanics.com/technology/gadgets/a15731/best-way-to-keep-li-ion-batteries-charged/>)

**John Goodenough—inventor of the lithium-ion battery**

Students might enjoy learning about the inventor of the lithium-ion battery, John Goodenough**.** In this 2017 NPR interview (3:24) the 95-year-old professor of material science at the University of Texas in Austin talks about his current work that may revolutionize this battery. (<http://www.npr.org/sections/alltechconsidered/2017/05/22/529116034/at-94-lithium-ion-pioneer-eyes-a-new-longer-lasting-battery>)

Biographical information about Professor Goodenough can be found here: <https://en.wikipedia.org/wiki/John_B._Goodenough>.

**Goodenough-Braga glass battery**

Information about the new Braga-Goodenough battery that uses a special glass as the electrolyte can be found on its Wikipedia site. The wiki also includes the skepticism surrounding the glass battery. (<https://en.wikipedia.org/wiki/Glass_battery>)

The University of Texas press release about the new Braga-Goodenough glass electrolyte battery can be found here: <https://news.utexas.edu/2017/02/28/goodenough-introduces-new-battery-technology>.

**Current research**

The Wikipedia page on battery research is very well organized in outline form, making it easy to find information about specific current findings. If you are assigning student projects on the recent developments in batteries, this would be a good first stop. (<https://en.wikipedia.org/wiki/Research_in_lithium-ion_batteries>)

Nature.com has a catalog of recent battery research papers. The site is equipped with a search tool that will help sift through the thousands of entries. This site will only allow you to read up to 8 articles before requiring a subscription to *Nature* or payment of a fee per article. (<https://www.nature.com/subjects/batteries>)

**ACS battery webinar**

“The Chemistry of Hello: Lithium-ion Batteries” (48:07) is the title of an American Chemical Society webinar featuring Dee Strand from Wildcat Discovery Technology and Mark Jones from Dow Chemical. The chemistry of cell phone lithium-ion batteries is presented in depth in order to answer common questions people ask concerning their cell phone battery. (<https://www.youtube.com/watch?v=l4uMuKShQvM&t=1638s>)

# About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.



**Teacher's Guide for**

### *“Teens and Depression”*

**December 2017/January 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Chemical bonding** | Antidepressant drug molecules use chemical bonding to block neurotransmitter reuptake channels. |
| **Catalysis** | When using the “lock and key” analogy to explain catalysis, link to its use to describe message transmission at a synapse. |
| **Organic functional groups** | While discussing organic functional groups, you can include the neurotransmitter molecules with an amino functional group. |
| **Organic structural diagrams** | While studying organic structures, note that this article uses abbreviated Lewis structures (skeletal formulas) to illustrate neurotransmitters. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:

**ELA-Literacy.RST.9-10.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**ELA-Literacy.RST.9-10.5.** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, and energy).

**ELA-Literacy.RST.11-12.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

**ELA-Literacy.RST.11-12.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

* Links to **Common Core Standards for Writing**:

**ELA-Literacy.WHST.9-10.2F.** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

**ELA-Literacy.WHST.11-12.1E.** Provide a concluding statement or section that follows from or supports the argument presented.

* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:

**ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.

**ELA-Literacy.WHST.11-12.1.A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

* Links to **Next Generation Science Standards**:

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

* **Disciplinary Core Ideas:**
* LS1.A: Structure and Function
* **Crosscutting Concepts:**
* Cause and effect: Mechanism and explanation
* Structure and function
* Stability and change
* **Science and Engineering Practices:**
* Constructing explanations and designing solutions
* Obtaining, evaluating, and communicating information
* **Nature of Science:**
* Scientific knowledge is based on empirical evidence

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the December 2017/January 2018 issue:

* Metric units
* Structural Formulas
* Fermentation
* pH
* Electrochemistry
* Oxidation & Reduction
* Amines
* Allotropes
* Physical properties
* London dispersion forces

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 76):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.
* **Graphic Organizer (p. 77):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers 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 |

* **Student Reading Comprehension Questions (p. 78-79):** The Student Reading Comprehension Questions are designed: to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.
* Most of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make decisions in their personal lives.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.

“Teens and Depression” *ChemMatters*, December 2017/January 2018 Issue

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

“A Close-up Look at the Quality of Indoor Air” (*ChemMatters*, April/May 2016 Issue)

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. 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. In 2014, fewer than one in ten adolescents had a major depressive episode. |
|  |  | 1. Depression has several symptoms, including irritability. |
|  |  | 1. Only one area of the brain is affected in a depressed person. |
|  |  | 1. Neurons are highly specialized nerve cells that communicate information. |
|  |  | 1. Chemicals transmit information between neurons. |
|  |  | 1. Patients with depression have low levels of neurotransmitters. |
|  |  | 1. When teens experience side effects using antidepressants, they should stop taking the drugs immediately. |
|  |  | 1. There are two major types of antidepressants, SSRIs and MAOIs. The “I” in both types stands for “inhibitor.” |
|  |  | 1. Recent studies have shown antidepressants may encourage the growth of new neurons. |
|  |  | 1. Treating depression involves a combination of therapies. |

## Graphic Organizer

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

“Teens and Depression” *ChemMatters*, December 2017/January 2018 Issue

**Directions**: ***As you read***, complete the graphic organizer below to compare SSRIs and MAOIs.

|  |  |  |
| --- | --- | --- |
|  | **SSRIs** | **MAOIs** |
| ***Examples*** |  |  |
| ***How they work*** |  |  |
| ***Side Effects*** |  |  |

**Summary:** On the back of this paper, write a short email (2-3 sentences) to a friend explaining the chemistry of depression

## Student Reading Comprehension Questions

“Teens and Depression” *ChemMatters*, December 2017/January 2018 Issue

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

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

1. When are sad and unhappy feelings considered clinical depression?
2. What reason does the author provide to propose the belief that depression and substance abuse are linked?
3. Complete the table below to identify the areas of the brain that shrink in people with symptoms of depression; describe the function of each area.

|  |  |
| --- | --- |
| **Affected brain area** | **Function of brain area** |
|  |  |
|  |  |
|  |  |

1. (a) Name the three parts of a neuron, and (b) describe how a signal is transmitted through each part.
2. (a) Describe a synapse. (b) Why is the synapse important?
3. (a) What is a neurotransmitter, and (b) how does it work?

**Student Reading Comprehension Questions, cont.**

“Teens and Depression” *ChemMatters*, December 2017/January 2018 Issue

1. What is the monoamine hypothesis?
2. (a) Name the three specific neurotransmitter chemicals referred to in the monoamine hypothesis. (b) How does the name “monoamine” describe these three chemicals?
3. (a) How do SSRIs work? (b) Explain how SSRIs’ ability to mimic serotonin’s chemical structure allows enough serotonin to be transmitted to the next neuron.
4. How do MAOIs work?
5. Give two reasons why it is important for doctors to monitor newly diagnosed and medicated patients.
6. What does depression research suggest about increasing the concentration of monoamines at synaptic terminals?

## Answers to Student Reading Comprehension Questions

1. **When are sad and unhappy feelings considered clinical depression?**

*Sad and unhappy feelings are considered clinical depression when they become chronic, prolonged and the person is unable to “will away” their bad mood.*

1. **What reason does the author provide to propose the belief that depression and substance abuse are linked?**

*A reason to think that depression and substance abuse are linked is that about 30% of teens with depression also have a substance abuse problem.*

1. **Complete the table below to identify the areas of the brain that shrink in people with symptoms of depression; describe the function of each area.**

|  |  |
| --- | --- |
| **Affected brain area** | **Function of brain area** |
| *amygdala* | *involved in memory and emotional reactions* |
| *thalamus* | *involved in speech, movement and learning* |
| *hippocampus* | *processes long-term memory* |

1. **(a) Name the three parts of a neuron and (b) describe how a signal is transmitted through each part.**

*The three parts of a neuron are dendrites, cell bodies and axons.*

*“A signal is received at the dendrite, travels through the cell body, and is released at the axon.”*

1. **(a) Describe a synapse. (b) Why is the synapse important?**
2. *A synapse is the space between the sending neuron’s axon and the receiving neuron’s dendrite.*
3. *The synapse is important because it is the place where information is passed via chemicals within the brain.*
4. **(a) What is a neurotransmitter, and (b) how does it work?**

*A neurotransmitter is a chemical that passes information from neuron to neuron.*

*Neurotransmitter chemicals are released from the axon of one neuron and received (across the synapse) by the dendrite of another.*

1. **What is the monoamine hypothesis?**

*The monoamine hypothesis states that low levels of monoamines cause inefficient signaling between neurons, resulting in symptoms of depression.*

1. **(a) Name the three specific neurotransmitter chemicals referred to in the monoamine hypothesis. (b) How does the name “monoamine” describe these three chemicals?**
2. *The three neurotransmitter chemicals referred to in the monoamine hypothesis are dopamine, norepinephrine, and serotonin.*
3. *The name “monoamine” describes each transmitter molecule that contains one amino (─NH2) group.*
4. **(a) How do SSRIs work? (b) Explain how SSRIs’ ability to mimic serotonin’s chemical structure allows enough serotonin to be transmitted to the next neuron.**
5. *SSRIs work by preventing serotonin reuptake.*
6. *SSRIs’ ability to mimic serotonin’s chemical structure allows them to tightly bind to the serotonin reuptake channel, preventing serotonin reuptake (thus allowing enough serotonin to be transmitted to the next neuron, restoring neural circuitry).*
7. **How do MAOIs work?**

*MAOIs work by inhibiting “the activity of monoamine oxidase to prevent the breakdown of monoamine neurotransmitters and increase their availability.”*

1. **Give two reasons why it is important for doctors to monitor newly diagnosed and medicated patients.**

*It is important for doctors to monitor newly diagnosed and medicated patients because*

1. *each person reacts differently to medication.*
2. *finding the right medication and dose may take time (trial and error) for the full effect and for side effects to ease as the body adjusts.*
3. **What does depression research suggest about increasing the concentration of monoamines at synaptic terminals?**

*Depression research suggests that increasing the concentration of monoamines at the synaptic terminals may encourage the growth of new neurons.*

# Possible Student Misconceptions

1. **“I’ve heard that only adults can become truly depressed.”** *This is a major misconception that may lead to teens being told to simply “cheer up”. In June 2016, scientists reported that 29.9% of high school students reported at least one major depressive episode during the past year.*
2. **“I can tell when someone is depressed because they look sad and walk around with their heads down.”** *There are other signs of depression besides looking sad. Depression may cause feelings of weakness and irritability, as well as changes in appetite, restlessness and substance abuse.*
3. **“My cousin told me that prescription drug treatment for depression is too strong for teens. He said that it’s better if they get over it by themselves.”** *Antidepressant medications have been shown to be effective in helping teens recover from depression. Untreated depression is the number one cause of teenage suicide.*
4. **“I’ve heard that once depression is treated with medication, it goes away completely.”** *Almost 75% of teenagers who experience a clinical depression episode may require further treatment later in life.*
5. **“I read that most people with depression can’t be helped.”** *Fortunately, this is not true because depression can be effectively treated in 90% of the cases through a combination of medication and therapy. Unfortunately, only one in three people with depression seek professional help.*

# Anticipating Student Questions

1. **“My mother has always suffered bouts of depression. If I’ve inherited depression, what can I do?”** *Depression often has a genetic component, so reduce your risk by creating a healthy life style for yourself. Manage your stress, stay connected with positive supportive friends, eat well, avoid drugs, exercise, and seek professional help if needed.*
2. **“Wow! The side effects of antidepressants sound worse than depression; are they really for teens?”** *Yes, antidepressants are often an effective way to treat teenage depression. However their use must be monitored carefully by a physician to avoid severe side effects.*
3. **“Why does teen depression affect girls more than boys?”** *Teen depression is twice as prevalent in girls. Girls experience twice as many “interpersonal stressors”, including cyberbullying, as boys and they react to these more strongly than boys.*
4. **“Are depressed kids always ‘loners’”?** *Depression doesn’t distinguish between “loners” and popular teens that socialize to avoid appearing depressed. The only connection is that depressed teens feel alone, even when surrounded by friends.*
5. **“Are the signs of teen depression the same as those of adults?”** *Teen depression often manifests itself differently from adult depression. Some depressed teens may become defiant and irritable, leading to being labeled as a “trouble maker”.*
6. **“When I feel depressed, my friend offers to share a few of her Paxil pills to get me over the slump. Is there a problem with this?”** *Always check with your doctor before taking medicine that was prescribed for someone else. For example, if an SSRI is taken with another medication that also increases serotonin the body’s reuptake system may be unable to handle the large excess of the neurotransmitter. When the body has too much serotonin a condition called serotonin syndrome occurs, resulting in excessive nerve cell activity. Side effects such as agitation, restlessness, muscle twitching, irregular heart beat and seizures require immediate medical attention. (*[*https://www.webmd.com/depression/guide/serotonin-syndrome-causes-symptoms-treatments#1*](https://www.webmd.com/depression/guide/serotonin-syndrome-causes-symptoms-treatments#1)*)*

# Activities

**Special note of caution: Due to the sensitivity of this topic, some teachers might prefer not to present some of the activities below to their students, considering that it might be more appropriate for students to discuss teen depression in a clinical educational setting, rather than in a chemistry class. Due to the need for extreme caution on the part of chemistry teachers in discussing this material, consultation with the school nurse or other professionals may be necessary if teachers intend to explore the topic in depth.**

**Simulations**

**This Web site allows stimulation of a neuron:** Note that the caution note above does not apply to this simulation, which is appropriate for all classes. This is a PhET simulation from the University of Colorado; the simulation is free, but teachers must register. There are tips on how to manipulate the diagram to show the ions moving across the membrane of the neuron. (<https://phet.colorado.edu/en/simulation/neuron>)

**Media**

**Video (0:28) “Teen Depression on the Rise”:** Video shows results of a November 2016 study published in the *Journal of Pediatrics* that finds a 37% increase in teen depression during the last decade without a corresponding increase in mental health treatment. An article explaining the results of this study accompanies the video. (<http://time.com/4572593/increase-depression-teens-teenage-mental-health/>)

**KhanAcademy video (11:09) “Treating Depression with Antidepressants”:** This educational video clearly explains neurotransmission using narration and illustration to describe the different mechanisms used by MAOIs and SSRIs and other types of antidepressants to correct the imbalance of neurotransmitters that results in depression. (OK for a chemistry class audience) (<https://www.khanacademy.org/science/health-and-medicine/mental-health/depression-and-related-disorders/v/treating-depression-with-antidepressants>)

**Lessons and lesson plans**

**Lesson plan—small group discussion (1–2 50-min. class periods):** In this well-designed lesson plan and suggested PBS program, “Depression: On the Edge”, students discuss their personal experiences with teenage depression. **NOTE that this program and lesson contain material that is probably more appropriate for psychology or health classes.** (<http://www.pbs.org/inthemix/educators/lessons/depression1/>)

**Projects and extension activities**

**Research and debate**─**Does a link exist between creativity and depression?** Watch the video “Creativity and Depression: What causes the link?” (3:46).(<https://www.youtube.com/watch?v=CtOKjHgNsQw>). Then use internet research to gather data to debate this question in class.

This URL for teachers provides examples of famous artists (musicians, painters, scientists) who endured harsh physical and emotional hardships during their early lives. They survived early experiences yet suffered bouts of depression throughout their later lives, bringing the question about a possible link between creativity and depression: (<https://blogs.scientificamerican.com/beautiful-minds/the-real-link-between-creativity-and-mental-illness/>)

**Research on antidepressants:** Compose a question about antidepressants, and use research from the internet to write a letter to a friend explaining what you discovered. Examples for teachers:

* What is the history of antidepressant use? (<http://www.sciencemuseum.org.uk/broughttolife/techniques/antidepressants> or <http://www.brainphysics.com/articles/treatment/medication/the-history-of-antidepressant-drugs>)
* Is the use of antidepressants by Americans increasing or decreasing? (<https://www.health.harvard.edu/blog/astounding-increase-in-antidepressant-use-by-americans-201110203624>)

**Research project to investigate whether heredity plays a role in teen depression:** Use the internet or other resources to collect data about the possibility of a link between heredity and teen depression. Here are three Web sites to use as an introduction to this study: <https://www.recoveryranch.com/articles/therapy/depression-heredity/>, <https://link.springer.com/article/10.1007/s10964-015-0306-0>, and <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3565713/>.

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



***30* Years of *ChemMatters !***

Available Now!

This article describes herbal supplements including St. John’s Wort (page 19) that contain the active ingredient hypericin, which decreases depression by inhibiting the action of monoamine oxidase. (Roth, C. Extracting Medicine from Plants. *ChemMatters*, 2003, *1* (21), pp 17–19)

This article is an excellent reference with a focus on the chemistry of depression. Chemical structures are included with descriptions of the processes involved in the ability of SSRIs, MAOIs, and a third class of antidepressants, tricyclics, to reduce depression. (Kimbrough, D. More than Blue. *ChemMatters*, 2005, *1* (23), pp 8–11)

# Web Sites for Additional Information

**General information**

This Web site, “Transforming the understanding and treatment of mental illness”, prepared by the U.S. National Institute of Mental Health (NIMH), is a very comprehensive educational resource that covers most of the material in the *ChemMatters* Scaduto article and in this Teacher’s Guide. Through text and audio accompanied by excellent diagrams (option: a downloadable pdf version), “Brain Basics” covers the growing brain, how it works, genetics and basic brain research. (<https://www.nimh.nih.gov/health/educational-resources/brain-basics/brain-basics.shtml>)

**Teen depression—signs and dangers**

This Mayo Clinic Web site is a “go-to” place for information about teen depression. In the overview, teen depression is defined as a “serious mental health problem”. Links on the site include emotional and behavioral changes, diagnosis and treatment, and self-management. (<http://www.mayoclinic.org/diseases-conditions/teen-depression/home/ovc-20164553>)

The National Institute of Mental Health (NIH) runs clinical trials for the “Teen Depression Study: Understanding Depression in Teenagers”. Their Web site lists signs and symptoms of teenage depression and invites those who experience these most of the day or nearly every day for at least two weeks to consider joining the trials. (<https://www.nimh.nih.gov/health/topics/depression/index.shtml#part_145397>)

**Brain remodeling**

This paper describes the structural changes that occur in the brain due to stress and depression. Research data describes how these changes can be prevented and possibly reversed by mood-stabilizing medications. (<http://www.dbsalliance.org/site/PageServer?pagename=education_anxiety_stress_brain_structure>)

*Psychology Today* compares research data from magnetic resonance imaging (MRI) studies of the brains of individuals with psychiatric disorders and/or substance abuse problems to MRIs of healthy individuals. Scans show measurable size reductions in the key areas of brains affected by psychosis and/or substance abuse. (<https://www.psychologytoday.com/blog/heal-your-brain/201107/depression-and-anxiety-disorders-damage-your-brain-especially-when>)

**Neurotransmission**

“What is neurotransmission?” is designed as a 7–12 grade student teaching tool. In a two minute video, “Synaptic Transmission”, an animator draws diagrams, while text explains the process, and a list of defined vocabulary are included. (<https://www.sciencenewsforstudents.org/article/explainer-what-neurotransmission>)

This technical paper uses animations and text to explain how action potentials (electrical signals) are generated by ions as they move across the axon membrane and through ion channels. (<http://www.mind.ilstu.edu/curriculum/neurons_intro/neurons_intro.php>)

**Chemistry of neurotransmission**

**KhanAcademy video (11:09) “Treating Depression with Antidepressants”:** This educational video is safe to use in all chemistry classes. It clearly explains neurotransmission, using narration and illustration to describe the different mechanisms used by MAOIs and SSRIs and other types of antidepressants to correct the imbalance of neurotransmitters that results in depression. (<https://www.khanacademy.org/science/health-and-medicine/mental-health/depression-and-related-disorders/v/treating-depression-with-antidepressants>)

**Neurotransmitters—classification**

When classified by function, neurotransmitters can be described by their action in one of two ways, inhibitory (creating calm balance in the brain) and excitatory (stimulating the brain). The article uses this classification to separate a selection of neurotransmitters; information about each neurotransmitter is included. (<https://www.biotecharticles.com/Biology-Article/Neurotransmitters-and-its-types-347.html>)

This neurophysiology site contains excellent diagrams that illustrate how ionic action potentials are developed and their role in opening and closing ion channels. Neurotransmitters are classified by their chemistry based on molecular structure. (<https://courses.lumenlearning.com/boundless-ap/chapter/neurophysiology/>)

**Treatment options**

Medication—Two antidepressants for teens have been approved (with Black Box warnings) by the U.S. Food and Drug Administration (FDA): fluoxetine (Prozac) and escitalopram (Lexapro). Adolescent response to antidepressants varies, so their use must be carefully monitored, may induce suicidal behavior, and are considered less effective for teenagers than psychotherapy. (<http://www.mayoclinic.org/diseases-conditions/teen-depression/diagnosis-treatment/treatment/txc-20164566>)

Psychotherapy—This open-access paper explores research on the use of Cognitive-Behavioral Therapy (CBT) with depressed and suicidal adolescents. The rationale for the use of CBT with a focus on whether it effectively reduces suicidal thoughts and behaviors is developed through the results of prior studies and the specific techniques used. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3073681/>)

**Antidepressants**

Since antidepressant drugs have been developed to affect the behavior of neurotransmitters in different ways, this WebMd site is organized by links to different mechanisms: reuptake inhibitors, tetracyclics and SSRIs and tricyclics and MAOIs. Each section explains how the antidepressant works, which neurotransmitter it affects, and the relevant prescription drugs. (<http://www.webmd.com/depression/how-different-antidepressants-work#1>)

Harvard Medical School discusses the importance of reanalyzing both the published and unpublished prior trials investigating the effects on teens of the antidepressant Paxil. Due to poor methodology (drug company funding or results not published), one trial found Paxil safe and effective for teens, while another found it no more effective than a sugar pill placebo. (<https://www.health.harvard.edu/blog/anti-depressants-for-teens-201601229018>)

**Antidepressants—side effects**

The *Journal of Canadian Child Adolescent Psychiatry* published their 2016 Position Statement on the use of SSRIs and serotonin norepinephrine reuptake inhibitors (SNRIs) in children and adolescents, following a thorough review of the literature. A risk/benefit analysis of the data suggests that the SSRI fluoxetine (Prozac) is the best medication for adolescents suffering Major Depressive Disorder (MDD), due to its long half-life and lesser tendency toward suicide. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4791100/>)

This site provides lists of some SSRIs prescribed for children and teens by generic and brand names. Each name is linked to detailed information on uses, side effects, interactions, overdose, and an image of the medicine. (<http://www.webmd.com/depression/selective-serotonin-reuptake-inhibitors-ssris-for-childhood-and-adolescent-depression>)

**Causes—environmental and genetic**

This Harvard Health site can be a valuable classroom resource because it describes the effects of depression shown by brain images and neurotransmission. Environmental causes of depression such as stress, early childhood loss, grief, and the role of trauma are described. (<https://www.health.harvard.edu/mind-and-mood/what-causes-depression>)

A summary of research leading to a possible link between depression and genetics by Stanford University Medicine provides estimates of the risk of inheriting depression, and the “further reading” section gives links to many studies. Studies of twins (fraternal and identical) suggest that a combination of genes may lead to a predisposition to depression. (<http://depressiongenetics.stanford.edu/mddandgenes.html>)

# About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.



**Teacher's Guide for**

### *“The Write Stuff: The Fascinating Chemistry of Pencils”*

**December 2017/January 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Covalent bonding** | Students may be familiar with covalent bonds in rings such as benzene; however, graphite may provide a more tangible and familiar example of covalent bonds in rings for students. |
| **Polarity** | Polar and nonpolar properties of substances are often demonstrated with solubility, such as the non-mixing of oil (nonpolar) and water (polar). Using graphite pencils to write on paper as an example of a nonpolar-nonpolar interaction will provide students with another example of polarity in action. |
| **Allotropes** | Students may struggle with understanding the concept of allotropes. By providing concrete examples of the allotropic forms of carbon (graphite, diamond, and buckminsterfullerene) or using physical models of them, students may better grasp the distinction caused by bonding arrangements of the carbon atoms. |
| **Chemical/Physical properties** | The article provides excellent examples comparing the physical properties of lead and graphite. Extending the comparison to chemical properties could make an interesting lesson. In addition, comparing the chemical and physical properties of the allotropes of carbon may help students to understand the effects of bonding on the properties of matter. |
| **London Dispersion forces** | Described as "weak" attractions, students may believe that London Dispersion forces are not important or significant. By using London Dispersion forces between sheets of graphite that result in a solid, or the London Dispersion forces that adhere graphite to paper, as tangible examples, students may better understand the collective strength of this weak, nonpolar interaction. |
| **Delocalized electrons** | The sometimes complex concept of delocalized electrons is frequently taught using the structure of benzene (an excellent example); however, using graphite as an additional example and allowing students to rub the graphite between their fingers will provide a tactile experience that may enhance student learning and understanding of delocalized electrons. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:

**ELA-Literacy.RST.9-10.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

**ELA-Literacy.RST.9-10.5.** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, and energy).

**ELA-Literacy.RST.11-12.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

**ELA-Literacy.RST.11-12.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

* Links to **Common Core Standards for Writing**:

**ELA-Literacy.WHST.9-10.2F.** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).

**ELA-Literacy.WHST.11-12.1E.** Provide a concluding statement or section that follows from or supports the argument presented.

* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:

**ELA-Literacy.WHST.9-10.1B.** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.

**ELA-Literacy.WHST.11-12.1.A.** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

* Links to **Next Generation Science Standards**:

**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.

* **Disciplinary Core Ideas**:
* PS1.A: Structure and properties of matter
* PS2.B: Types of Interactions
* **Crosscutting Concepts:**
* Patterns
* Structure and function
* **Science and Engineering Practices**:
* Developing and using models
* Obtaining, evaluating, and communicating information
* **Nature of Science**:
* Science addresses questions about the natural and material world

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the December 2017/January 2018 issue:

* Metric units
* Structural Formulas
* Fermentation
* pH
* Electrochemistry
* Oxidation & Reduction
* Amines
* Allotropes
* Physical properties
* London dispersion forces

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 97):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

As an alternative to using an Anticipation Guide, consider the following idea:

Ask students to examine their ordinary pencils (not mechanical pencils), and complete a chart like the one below. Encourage them to write at least two “I see, I think, I wonder” statements for each pencil part.

|  |  |  |  |
| --- | --- | --- | --- |
| ***Pencil Drawing*** |  | | |
| ***Name of part*** |  |  |  |
| ***I see . . .*** |  |  |  |
| ***I think . . .*** |  |  |  |
| ***I wonder . . .*** |  |  |  |

* **Graphic Organizer (p. 98):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers 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 |

* **Student Reading Comprehension Questions (p. 99-100):** The Student Reading Comprehension Questions are designed: to encourage students to read the article (and graphics) for comprehension and attention to detail; to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment; and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.
* Most of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make decisions in their personal lives.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.

“The Write Stuff: The Fascinating Chemistry of Pencils” *ChemMatters*, December 2017/January 2018 Issue

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

“A Close-up Look at the Quality of Indoor Air” (*ChemMatters*, April/May 2016 Issue)

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. 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. Pencils do not contain lead. |
|  |  | 1. A mark from graphite is lighter than a mark from lead. |
|  |  | 1. Today’s pencils write with a mixture of carbon and clay. |
|  |  | 1. The metal ring that holds the eraser on a pencil is made of iron. |
|  |  | 1. Graphite forms thin sheets that slide off and stick to paper. |
|  |  | 1. Graphite and the cellulose in paper are both nonpolar. |
|  |  | 1. Some erasers are made of plastic or vinyl. |
|  |  | 1. The first electronic grading machines depended on the electrical conductivity of graphite to score tests. |
|  |  | 1. Pink erasers contain volcanic pumice to act as an abrasive. |
|  |  | 1. Particles of graphite are removed by rubber erasers in a chemical process. |

## Graphic Organizer

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

“The Write Stuff: The Fascinating Chemistry of Pencils” *ChemMatters*, December 2017/January 2018 Issue

**Directions**: **Directions**: ***As you read***, complete the graphic organizer below to describe what you learned about the chemistry of all parts of pencils.

|  |  |  |
| --- | --- | --- |
| ***Pencil part*** | ***What it is made of*** | ***The chemistry of how it works*** |
| ***Pencil core (“lead”)*** |  |  |
| ***Painted part*** |  |  |
| ***Metal holding eraser*** |  |  |
| ***Eraser*** |  |  |

**Summary**: On the back of this paper, write a one-sentence summary (20 words or less) of the article.

## Student Reading Comprehension Questions

“The Write Stuff: The Fascinating Chemistry of Pencils” *ChemMatters*, December 2017/January 2018 Issue

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

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

1. What is the material used in a pencil lead?
2. In ancient writing utensils, what element was mixed with lead to form an alloy making darker marks?
3. Explain the circumstances of when and how the lead in pencils was replaced.
4. In the table below, list and compare/contrast four properties of lead and graphite.

|  |  |  |
| --- | --- | --- |
| **Property** | **Lead** | **Graphite** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

1. Why is clay added to most pencil leads?
2. What is an allotrope? Explain the reason for differences between allotropes.

**Student Reading Comprehension Questions, cont.**

“The Write Stuff: The Fascinating Chemistry of Pencils” *ChemMatters*, December 2017/January 2018 Issue

1. Explain why graphite is soft and slippery to the touch.
2. Why are most pencils sold in the U.S. yellow in color?
3. How does pencil lead cling to paper?
4. What happens to rubber when it is vulcanized?
5. How do pencil erasers work to remove marks?
6. Why do rubber pencil erasers get hard and brittle over time and not work well?

## Answers to Student Reading Comprehension Questions

1. **What is the material used in a pencil lead?**

*A pencil lead is composed of graphite, a form of carbon.*

1. **In ancient writing utensils, what element was mixed with lead to form an alloy making darker marks?**

*In ancient writing utensils, the element mixed with lead forming an alloy making darker marks was tin.*

1. **Explain the circumstances of when and how the lead in the ancient writing stylus was replaced.**

*In the 1500s in England, a storm uprooted a tree growing over a deposit of pure graphite. Local people discovered that the graphite could produce dark marks on a variety of substances. With this discovery, graphite for use as a writing instrument grew rapidly.*

1. **In the table below, list and compare/contrast four** **properties of lead and graphite.**

*Possible answers include any combination of these:*

|  |  |  |
| --- | --- | --- |
| ***Property*** | ***Lead*** | ***Graphite*** |
| ***Appearance*** | *Silvery gray* | *Silvery gray* |
| ***Conduction*** | *Good* | *Good* |
| ***Hardness*** | *Relatively soft* | *Relatively soft* |
| ***Density*** | *11.3 g/mL* | *2.3 g/mL* |
| ***Color of mark*** | *Lighter* | *Very dark* |

1. **Why is clay added to most pencil leads?**

*Clay is added to most pencil leads to increase the hardness of the graphite in the pencil leads, so that it is less likely to smudge or break.*

1. **What is an allotrope? Explain the reason for differences between allotropes.**

*“An allotrope is a different form of the same element, due to different bond arrangements in the substances.”*

1. **Explain why graphite is soft and slippery to the touch.**

*Graphite is soft and slippery to the touch because it is composed of carbon atoms bonded with three other carbon atoms forming thin sheets of rings. These sheets are weakly held together by London Dispersion forces, allowing the sheets to easily slide off of each other.*

1. **Why are most pencils sold in the U.S. yellow in color?**

*Most pencils in the U.S. are yellow because, in the 1800s, the world's best graphite came from China where pencils were painted yellow to signify royalty. Others followed the trend, and yellow became the standard color for pencils.*

1. **Why does pencil lead cling to paper?**

*Pencil lead clings to paper when the graphite "lead" flakes off as you write or draw. The cellulose fibers in paper have a large surface area and catch many of the graphite flakes. Because graphite and cellulose are both nonpolar, the flakes attract to the paper due to London Dispersion forces.*

1. **What happens to rubber when it is vulcanized?**

*When rubber is vulcanized, sulfur is added to natural rubber and heated. The heat causes crosslinks between the rubber polymer chains and the sulfur, producing a more durable material.*

1. **How do pencil erasers work to remove marks?**

*Pencil erasers work by physically removing the graphite particles from the paper. Because rubber, graphite, and cellulose are nonpolar substances, only weak, London Dispersion forces bind the graphite to the paper. The nonpolar forces between the eraser and the graphite are stronger than the nonpolar forces between the graphite and the paper, so the eraser removes the mark.*

1. **Why do rubber pencil erasers get hard and brittle over time and not work well?**

*Rubber pencil erasers get hard and brittle over time and don't work well because the rubber is oxidized. The oxidation from ultraviolet light, ozone, and oxygen causes the long polymer chains of the soft rubber to break up, creating more cross-linkages between the chains, making the eraser harder and less effective.*

# Possible Student Misconceptions

1. **“Wooden pencils are the same throughout the world.”** *While there are many similarities, there are also differences among pencils in the world. Most pencils in the U.S. have erasers on the end, but few pencils do in Europe. In the U.S., a system of numbers from 1–4 to designate the grade of graphite hardness, but in Europe, a lettered system is used, such as HB. There are also some differences in countries for the degree of hardness of the pencil leads and the type of wood used to encase the lead.*
2. **“Wooden pencils and mechanical pencils use the same type of lead.”** *Both wooden and mechanical pencils typically use a mixture of graphite and clay for the lead. However, mechanical pencil lead may also contain a polymer material to allow their (often) smaller diameter lead to be strong and yet flexible. Mechanical pencil leads made only with graphite and clay that are smaller than 0.9 mm are brittle enough to break under normal writing stresses.*
3. **“You can get lead poisoning from a pencil.”** *Many people understand that the "lead" in a pencil is not made of elemental lead. So, you cannot get lead poisoning from the graphite core of a pencil. However, before the 1970s, the yellow color popular on most pencils contained as much as 12% lead in the paint. If a people chewed on that yellow lead-based paint, they would ingest a small amount of lead. Under most circumstances, the amount would not have been sufficient to cause lead poisoning. Today, the yellow paint on pencils is lead free.*

# Anticipating Student Questions

1. **“Why is it called "lead" if pencils don't contain the element lead?”** *Ancient writing utensils often contained the element lead. However, in the 1500s, graphite (called plumbago—meaning “lead ore”—due to its similar appearance to lead) began to replace lead. The name "lead" stuck due to its earlier usage and similarities to lead.*
2. **“Why do scanned answer sheets suggest using only #2 pencils for marking?”** *Scanned answer sheets are scored by optical mark readers registering light reflected from the answer sheet. The marks on the answer sheet must be dark enough to absorb (not reflect) light but not smear and make erroneous marks. The #2 pencil happens to be the perfect combination of darkness and smudge-resistance. Harder pencils (#3 or #4) make marks that are too light or too hard, tearing the paper, while softer #1 pencils make too many smudges.*
3. **“How are colored pencils made?”** *Colored pencils, unlike writing pencils, do not contain graphite. Instead, colored pencils have a core made from wax or oil containing binders, additives, and colored pigments. These substances are blended, shaped, and sandwiched into a wooden case similar to graphite pencils.*
4. **“How do they get the pencil lead into the center of the wooden pencil?”** *Pencil lead is much too soft and brittle to insert it into a hollow cylinder inside of the wooden pencil without breaking. Instead, manufacturers groove out a space in each half of the wooden pencil blank, drop a pencil lead in the half-groove on one side of the wooden blank, and then glue the top half over the bottom with the pencil lead now trapped inside. The finished pencil then can be shaped into a hexagon (to minimize rolling) or finished as a round shape. See "How pencils are manufactured" in Web Sites for Additional Information (below) for links to two videos on pencil manufacturing.*

# Activities

**Labs and demos**

**Lab measuring the electrical resistance of graphite from a pencil:** Graphite is a conductor, and this simple activity from Flinn Scientific directs students to study the relationship between the length of graphite and its resistance. Student directions and the worksheet are provided, along with tips for success. (<https://www.flinnsci.ca/api/library/Download/f685c456a24b4886a835ebe5b9096cf5>)

**Demonstration of delocalized electrons in graphite analogy:** To demonstrate an analogy of graphite with its sheets of carbon atoms loosely attached by delocalized electrons, teachers/students can use a small stack of sheets of loose writing or copy paper. The sheets of paper are loosely attracted (try gently lifting one sheet of paper from the stack) by weak forces which hold the sheets together (similar to delocalized electrons in graphite), and can easily slide (like graphite) when the stack of papers is sheared between the palms of the hands.

**Simulations**

**Simulation of polarity:** The PhET simulation, “Molecule Polarity”, allows students to manipulate the electronegativity of atoms in a molecule to observe how that affects its polarity. Students observe how the molecule behaves in an electric field and how the bond angle affects both molecular shape and polarity. (<https://phet.colorado.edu/en/simulation/molecule-polarity>)

**Simulation of, and an activity for, intermolecular forces:** This activity, “Intermolecular Forces”, from the American Association of Chemistry Teachers (AACT) uses student worksheets, questions, and a simulation comparing dipole-dipole to London Dispersion forces. The Web site is complete with a teacher guide, the student activity, answer key, and a link to the simulation. (<https://teachchemistry.org/classroom-resources/intermolecular-forces>. Note that this link is only available to AACT or ACS members.)

**Media**

**Video explaining intermolecular forces:** "Intermolecular Forces" (8:35) from the Khan Academy reviews all of the intermolecular forces using diagrams. The explanation of London Dispersion forces, which are emphasized in the Rohrig pencil article, begins at 5:50 in this video: <https://www.khanacademy.org/science/biology/chemistry--of-life/chemical-bonds-and-reactions/v/intermolecular-forces-and-molecular-bonds>.

**Video of the carbon allotropes:** “Diamonds, Pencils, and Buckyballs: A Look at Buckminsterfullerene” (6:00) focuses on the discovery of buckyballs, but it also illustrates and explains the carbon allotropes. This video is part of the National Science Foundation's, *Science 360* video collection. [(https://science360.gov/obj/video/19bd995d-4ff6-44c6-83ca-d3bac9bc8f6d/diamonds-pencils-buckyballs-look-buckminsterfullerene](file:///C:\Users\Bill\AppData\Local\Packages\Microsoft.MicrosoftEdge_8wekyb3d8bbwe\TempState\Downloads\(https:\science360.gov\obj\video\19bd995d-4ff6-44c6-83ca-d3bac9bc8f6d\diamonds-pencils-buckyballs-look-buckminsterfullerene))

**Lessons and lesson plans**

**Carbon allotropes lessons and activities:** “Allotropes of Carbon : It's All in the Way You're Put Together” is a lesson series of 2.5–3 hours total time, where students learn about four carbon allotropes (including nanotubes) through student worksheets and modeling. The resource is complete, providing student pages, teacher support, materials list, expected answers, background material, and references. (<http://www.physics.purdue.edu/psas/docs/Allotropes%20of%20Carbon.pdf>)

**Cross-curricular lessons about pencils:** The Mineral Information Institute's *Everyday Uses of Minerals* guide includes in the series “How Many Countries Does It Take to Make a Pencil?” Lessons related to science, math, language arts, and geography provide writing, research, and science activities which may be a bit elementary, but may be useful or could be modified. (<http://www.kennecott.com/library/media/everyday.pdf>)

**Projects and extension activities**

**Modeling carbon allotropes and understanding hydrocarbons:** This series of four activities provides extensions for building carbon allotropes and organic molecule models, constructing and naming hydrocarbons, and making marbled paper. The materials needed are inexpensive and readily available; however, there are few teacher resources provided. (<https://www.rainbowresource.com/pdfs/products/prod032392_smpl1.pdf>)

**Conductivity of pencil lead:** Graphite pencil lead is an electrical conductor and that property can be used to in the project, Pencil Lead Light Bulb, which has Next Generation Science Standards identified. D-cell batteries, mechanical pencil leads, and assorted wire and clamps are assembled to produce the primitive light bulb. (<http://scactivities.cikeys.com/pencil-lead-lightbulb/for-teachers/>)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



***30* Years of *ChemMatters !***

Available Now!

This article compares graphite and diamond with respect to properties and bonding. Author Wood also explains the process of forming diamonds by chemical vapor deposition. (Wood, C. Two Faces of Carbon. *ChemMatters*, 2004, *22* (4), pp 4–6)

The serendipitous discovery of graphite for writing is only one example of an accidental discovery. Vaseline, Silly Putty, and aspartame are other serendipitous discoveries detailed in this interesting article. (Rohrig, B. Serendipitous Science. *ChemMatters*, 2007, *25* (3), pp 4–6)

Read this *ChemMatters* article for additional information and pictures about pencils and graphite that was reprinted from *Chemical and Engineering News* (see reference below). (Ritter, S. What's That Stuff? Pencils & Pencil Lead. *ChemMatters*, 2007, *25* (3), pp 11–12)

The Teacher's Guide for “What's That Stuff? Pencils & Pencil Lead” (above) provides additional information on allotropes, graphite, and student projects using graphite pencils.

For more information on diamond and graphite allotropes of carbon including van der Waals forces, bonding, chemical structures, and properties read this *ChemMatters* article. (Sicree, A. Graphite versus Diamond: Same Element but Different Properties. *ChemMatters*, 2009, *27* (3), pp 13–14)

The Teacher's Guide for “Graphite versus Diamond: Same Element but Different Properties” (above) provides more details on allotropes, graphite, pencils, and building a model of diamond from a template that appeared in an April 1990 issue of *ChemMatters*.

This article examines graphene (graphite that is only one atom thick) for potential uses in flexible solar panels, foldable cell phones, and bionic devices. Atomic structures of six common forms of carbon and a link to a video podcast are provided. (Tinnesand, M. Graphene: The Next Wonder Material? *ChemMatters*, 2012, *30* (3), pp 6–8)

The Teacher's Guide for “Graphene: The Next Wonder Material?” (above) provides background information on carbon allotropes, an activity with sticky tape to produce graphene, and numerous resources on graphene.

This *ChemMatters* article explains these serendipitous chemical discoveries: the synthesis of urea, radioactivity and the discovery of radium, and buckyballs. (Haines, G. "Chance Favors the Prepared Mind": Great Discoveries in Chemistry. *ChemMatters*, 2012, *30* (3), pp 17–19)

The Teacher's Guide for "’Chance Favors the Prepared Mind’": Great Discoveries in Chemistry” (above) provides additional information on each of the three discoveries. Additional information on the carbon allotrope buckyballs relates to the Rohrig pencil article.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

This article complements the Rohrig pencil article, providing details on the history of writing, the modern pencil, and making the pencil lead. A table with chemicals used (and their source) in making a pencil is provided. (Encke, F. The Chemistry and Manufacturing of the Pencil Lead. *J. Chem. Educ.*, 1970, *47* (8), pp 575–576; <http://pubs.acs.org/doi/pdf/10.1021/ed047p575>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

This is the original publication of “Pencils and Pencil Lead”, which was reprinted in the *ChemMatters* October 2007 issue as “What's That Stuff? Pencils & Pencil Lead”. (Ritter, S. Pencils and Pencil Lead. *Chem. Eng. News.*, 2001, *79* (42), p 35; <http://pubs.acs.org/doi/pdf/10.1021/cen-v079n042.p035>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal; however, the article is available free at <http://pubs.acs.org/cen/whatstuff/stuff/7942sci4.html>.)

The origin of the chemical term allotrope is detailed in this article. (Jensen, W. The Origin of the Term Allotrope. *J. Chem. Educ.*, 2006, *83* (6), pp 838–839; <http://pubs.acs.org/doi/pdf/10.1021/ed083p838>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

With proper equipment and support, high school students can build and operate a fullerene generator using graphite for the source material, and study properties of fullerenes. Supporting material and resources are provided in the article. (Davis, S., et al. Exploring Carbon's Allotropy: A Pupil-Led Synthesis of Fullerenes from Graphite. *J. Chem. Educ.*, 2015, *92* (7), pp 1263–1265; <http://pubs.acs.org/doi/pdf/10.1021/ed500709f>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

# Web Sites for Additional Information

**Pencils**

**“**20 Things You Didn't Know About…Pencils” presents some interesting (and short) facts about pencils from *Discovery* magazine. (<http://discovermagazine.com/2007/may/20-things-you-didnt-know-about-pencils>)

Numerous links to articles and publications related to everything about pencils, pencil collecting, pencil history, and pencil essays can be found at The Pencil Pages Web site. (<http://www.pencilpages.com/articles/index.htm>)

**How pencils are manufactured**

The History Channel provides this informative video, “How a Pencil Is Made” (5:42), which shows the steps in making a pencil with an emphasis on the graphite/clay lead, and following up with sandwiching it in wood, painting, attaching the eraser, and sharpening the finished product. (<https://www.youtube.com/watch?v=zZHp1fGdAWE>)

For another look at how pencils are made with greater details on the wooden pencil case and shaping the pencil, see <https://www.youtube.com/watch?v=WgiOvepQ6B0&feature=youtu.be>.

**Erasers**

The *New York Times Magazine* provides information about the history and invention of the built-in pencil eraser in “Who Made that Built-in Eraser?” at <http://www.nytimes.com/2013/09/15/magazine/who-made-that-built-in-eraser.html?mcubz=0>.

Interesting facts from *The Atlantic* about pencil erasers are located at <https://www.theatlantic.com/technology/archive/2013/08/10-things-you-probably-did-not-know-about-eraser-technology/279028/>.

**Serendipitous science**

The Rohrig pencil article described the discovery of graphite for writing as serendipity. The Mental Floss Web site highlights twenty-four additional scientific discoveries made as a fortunate accident, including Post-it Notes, the heart pacemaker, and Viagra—plus a video, "24 Unintended Scientific Discoveries" (10:16), on these discoveries; they can be found at <http://mentalfloss.com/article/53646/24-important-scientific-discoveries-happened-accident>.

"Scholars and Scientists Explore Factors Underlying Serendipitous Discoveries", published by the University of Chicago explores possible factors which may influence serendipitous discoveries, such as having teams of people collaborating who may not normally work together or looking at phenomena with a different mind-set. (<https://news.uchicago.edu/article/2014/06/19/scholars-and-scientists-explore-factors-underlying-serendipitous-discoveries>)

**Rubber and vulcanization**

Natural latex rubber is too gummy to be used as an eraser, but Charles Goodyear is credited with learning how to modify latex with heat and sulfur. Read more about his discovery at <https://connecticuthistory.org/charles-goodyear-and-the-vulcanization-of-rubber/>.

The in-depth report, "Rubber Chemistry", from Matador Rubber, includes structure, synthesis, properties, synthetic rubbers, reactions of rubbers, and various methods of vulcanization. You can find it at <http://laroverket.com/wp-content/uploads/2015/03/rubber_chemistry.pdf>.

**Carbon allotropes**

The University of Colorado Web site, Chapter 3.3 “Carbon – An Amazingly Allotropic Element”, provides an excellent explanation of the carbon allotropes, including carbon allotrope diagrams, hybridization of carbon orbitals, and descriptions of the carbon allotropes. (<http://virtuallaboratory.colorado.edu/CLUE-Chemistry/chapters/chapter3txt-3.html>)

For a simpler explanation of the carbon allotropes graphite and diamond, see this short *Scientific American* article, "How Can Graphite and Diamond Be So Different If They Are Both Composed of Pure Carbon?" (<https://www.scientificamerican.com/article/how-can-graphite-and-diam/>)

**London Dispersion forces**

The Chemistry LibreTexts™ Web site provides a clear explanation of London Dispersion forces and includes a quick animation. Induced dipoles and interaction energy are also included in the article, "London Dispersion Interactions". (<https://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Physical_Properties_of_Matter/Atomic_and_Molecular_Properties/Intermolecular_Forces/Specific_Interactions/London_Dispersion_Interactions>)

**Delocalized electrons**

The Chemistry LibreTexts™ Web site includes explanations and useful diagrams to introduce the concept of delocalized electrons using molecular orbital theory. The information provides numerous methods of indicating electron movement and resonance structures. (<https://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Chemical_Bonding/Valence_Bond_Theory/Delocalization_of_Electrons>)

An in-depth discussion of delocalized electrons is found on this California Institute of Technology Web site. Information includes hybrid orbitals, single and multiple bonds in carbon atoms, delocalized orbitals in benzene, and polyatomic molecules. (<https://authors.library.caltech.edu/25050/14/Chapter_13.pdf>)

**Graphite as a lubricant**

Find a diagram of the structure of graphite indicating the van der Waals attractions and an explanation of why graphite is an excellent dry lubricant at <http://www.substech.com/dokuwiki/doku.php?id=graphite_as_solid_lubricant>.

Compare the properties and uses of common dry lubricants including graphite, molybdenum disulfide, PTFE, and boron nitride. The site includes structures for molybdenum disulfide and graphite. ([http://www.tribology-abc.com/abc/solidlub.htm#graphite](http://www.tribology-abc.com/abc/solidlub.htm%23graphite))

**Pencil sharpeners**

For a picture of the mechanical pencil sharpener that African-American inventor John Lee Love designed, and his patent application, read "Pencil Patents: John Lee Love's Portable Pencil Sharpener". (<https://pencils.com/pencil-patents-john-lee-love-s-portable-pencil-sharpener/>)

"How the Pencil Sharpener Was Invented" from the Gizmodo Web site provides additional mechanical pencil sharpeners from French and British inventors with links to several other writing-related sources; see <https://gizmodo.com/how-the-pencil-sharpener-was-invented-1682242025>.

**Mechanical pencils**

This brief article, "History of the Mechanical Pencil – Inventor of Mechanism", explains the history of the mechanical pencil. (<http://www.historyofpencils.com/writing-instruments-history/history-of-mechanical-pencils/>)

**Optical mark recognition machines**

The rise of standardized multiple choice testing is linked to the use of answer sheets which could be scanned and scored by machine. "Multiple Choice and Testing Machines: A History" explains and shows a diagram and the patent for an early optical scoring machine. (<http://hackeducation.com/2015/01/27/multiple-choice-testing-machines>)

The explanation for why test takers must use #2 pencils on machine-scored (Scantron) forms is found at <http://www.todayifoundout.com/index.php/2010/10/why-you-used-to-have-to-use-2-pencils-with-scantron-forms/>.

**Yellow paint on pencils**

Many pencils are painted yellow as the Rohrig article explains. Before the 1970s, that paint may have contained the element lead, and an analysis of that paint is found in "Lead in Paint on Pencils" from the National Center for Biotechnology Information at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1937194/pdf/hsmhahr00011-0009.pdf>.

# About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.

E-mail: [bbleam@verizon.net](mailto:bbleam@verizon.net)

Susan Cooper prepared the anticipation and reading guides.

Terri Taylor, *ChemMatters* Teacher’s Guide interim editor, coordinated production and prepared the Microsoft Word and PDF versions of the Teacher’s Guide.

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.

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