



**February/March 2019**

Table of Contents

[“Making Sense of Milk”............................................................. 2](#_Toc536362577)

[“What’s Sunless Tanner?” 22](#_Toc536362590)

[“The Periodic Table Turns 150: Is the Best Yet to Come?” 40](#_Toc536362603)

[“Clean & Green” 59](#_Toc536362616)

[Standards and Vocabulary 77](#_Toc536362629)

[About the Guide 79](#_Toc536362630)

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

**Teacher’s Guide**



**Teacher's Guide for**

# “Making Sense of Milk”

**February/March 2019**

**Table of Contents**

[Tools and Resources 3](#_Toc529098364)

[Connections to Chemistry Concepts 3](#_Toc529098365)

[Possible Student Misconceptions 4](#_Toc529098367)

[Anticipating Student Questions 6](#_Toc529098368)

[Activities 8](#_Toc529098369)

[References 10](#_Toc529098370)

[Web Resources for More Information 11](#_Toc529098371)

[Reading Supports 13](#_Toc529098372)

[Anticipation Guide 15](#_Toc529098373)

[Graphic Organizer 16](#_Toc529098374)

[Student Reading Comprehension Questions 17](#_Toc529098375)

[Answers to Reading Comprehension Questions 19](#_Toc529098376)

### *Tools and Resources*

### Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Mixtures** | The graphics of whole milk and homogenized milk in this article are useful while discussing the concept of mixtures. Milk is used as an example of both a homogeneous mixture, due to the sugars dissolved in the water portion, and a heterogeneous mixture, due to the dispersion of fat particles throughout the milk. |
| **Molecular attractions** | The descriptions of the hydrophobic and hydrophilic actions of the spherical micelles in milk provide an example of polar and nonpolar attractions in molecules. |
| **Aqueous systems** | During a unit on aqueous systems, the article’s discussion of milk as a suspension, a colloid, and an emulsion provides a unique example of one such system. |
| **Biochemistry** | The article shows that milk contains many of the types of molecules covered in a unit on biochemistry. The comparison of the contents of the dairy and non-dairy milks in terms of proteins, carbohydrates, lipids, and the micronutrients such as minerals and vitamins provides an example of a commercial application of these compounds. |
| **Proteins** | The discussion of the protein quality of cow’s milk compared to that of the non-dairy milks complements lessons about complete proteins and the nine amino acids not produced by the human body. |
| **Density** | The description of non-homogenized milk separating into a fatty cream fraction on top of a watery fraction can be used during a lesson about density. |

### Possible Student Misconceptions

1. **“Milk is milk. Plant-based milk is the same nutritionally as cow’s milk.”** Just because a product is labeled “milk” does not mean it has the same nutritional content as cow’s milk. Very few plant-based milks have the same nutritional profile that cow’s milk does. Except for soy and pea protein milk, most plant-based milks have very little protein. Other protein components, like immunoglobulins, are exclusive to cow, goat, or sheep milk. To come closer to the vitamin and mineral profile of milk, some plant-based products are fortified with the vitamins and minerals found in cow’s milk. Some of the milk alternatives have sugar added to them to improve their taste. When shopping for an alternative to milk, reading the labels is very important.
2. **“If young children do not drink milk they will not develop strong bones or teeth.”** Children do not necessarily have to drink milk in order to develop strong bones or teeth. As long as children’s’ diets contain the appropriate amounts of calcium, protein, and vitamin D necessary for bone development, they should develop normally. Some children do not drink milk but love cheese and yogurt. They get most of the same nutrients in milk products as they do from milk. But if a child cannot eat dairy, dark green vegetables provide a good source of calcium, and oatmeal and beans provide a good source of protein. Spending time outdoors should give a child enough vitamin D, but vitamins can also be supplemented in a multivitamin.
3. **“I’m lactose intolerant, so I can’t drink milk at all.”** A lot of people who are lactose intolerant can still drink cow’s milk if the lactose is removed. Lactase tablets can be taken when ingesting milk or milk products. The lactase enzyme will break down the lactose present into glucose and galactose. So, unless you’re also galactose intolerant, you should be able to drink cow’s milk after adding the enzyme lactase. There is also a type of milk on the market called Lactaid. It is cow’s milk that has had the lactose removed. Many people who have problems with lactose intolerance do not have a problem with dairy products that have been fermented, like cheese and yogurt, because they do not contain as much lactose. People who are lactose intolerant should be able to drink any of the non-dairy kinds of milk.
4. **“The majority of humans do not have a problem with digesting lactose.”** When you consider the worldwide population, there are more people who are lactose *in*tolerant than lactose tolerant. The enzyme lactase is produced in the human small intestine prior to birth and typically slowly decreases during childhood. A mutation in the gene responsible for lactase production caused the production to persist past weaning, into adulthood. One mutation that allows for lactase persistence (meaning, lactose *tolerance*) is seen in persons of ancient central European ancestry, while other variations of the gene mutation are seen in populations from North Africa. It is estimated that the mutation occurred in populations around central Europe around 7,500 years ago. When you compare current world populations for lactase persistence, over 90% of northern Europeans, Scandinavians, and Irish are lactase persistent while only 5% of Asians and Africans have the mutation for lactase persistence. Therefore, 95% of Asians and Africans, who constitute the bulk of the world’s population, are lactose *in*tolerant. Native Americans also do not exhibit the mutation for lactase persistence and most are lactose intolerant. In the United States, you would have to attribute to your ancestry your ability to produce lactase and, thus, your lactose tolerance, as an adult. (<https://www.sciencedaily.com/releases/2009/08/090827202513.htm> <https://en.wikipedia.org/wiki/Milk>)
5. **“Lactose intolerance and milk allergies are the same thing”.** Milk allergies are different from lactose intolerance, even though they have some of the same symptoms. With either lactose intolerance or milk allergies you may have diarrhea, nausea, abdominal cramps, bloating, or gas but, with milk allergies, you may also have a rash, hives, swelling of the lips and face, as well as tightness in the throat and trouble swallowing. Lactose intolerance is caused by a lack of lactase production, while milk allergies are caused by a sensitivity to a protein specific to milk. They are more dangerous and can be life-threatening. Milk allergies are definitively diagnosed with allergy testing. Lactose intolerance can be definitively diagnosed by monitoring the serum glucose level after administering lactose. Persons who do not make lactase do not have a change in their glucose level while those who do make lactase will exhibit an increase in serum glucose.

### Anticipating Student Questions

1. **“Milk contains hormones? Are these in there naturally or are they in milk because the cows are receiving supplements? What hormones are in milk?”** The hormones found in milk are there naturally. Cows, like humans, produce a multitude of hormones that can pass into their milk. Pregnant cows produce almost 20 times more estrogen than nonpregnant cows; therefore, the greater the number of pregnant cows in the herd being milked, the higher the estrogen content of the milk will be. Besides estrogen, some of the other hormones that cross over into milk are progesterone, androgens, corticosteroids, cortisol, gonadotropin-releasing hormone, luteinizing hormone, thyrotropin-releasing hormone, somatostatin, insulin, calcitonin, parathyroid hormone-related protein, erythropoietin, and melatonin**.** Most hormones are fat soluble and are dissolved in the fatty portion of milk. When you drink milk, any of the hormones that are absorbed in the digestive tract are broken down by the liver, so these hormones in milk are never active in humans. Some farmers give their cows bovine growth hormone (BGH) or bovine somatotropin (BST) because it causes the cows to produce more milk. BST is not active in humans, and any that remains intact after pasteurization is digested like any other protein in the diet. However, the BST causes an increase in insulin-like growth factor-1 (IGF-1), which is the same as that produced by humans. The increased IGF-1 in milk from treated cows is still less than 1% of what the human body normally produces, so, statistically, it does not increase the amount of circulating IGF-1 in the body. If you are still concerned about hormones in your milk, you could switch to skim milk which is hormone free since it does not have any of the fat that contains the hormones. (<http://igrow.org/livestock/dairy/hormones-whats-in-your-milk/>)
2. **“What are immunoglobulins and cytokines?”** Immunoglobulins and cytokines are two classes of protein molecules that are involved with the body’s immune response. Before an infant can produce its own immunoglobulins, he/she receives them from the mother through the placenta. After birth, the infant receives immunoglobulins from the mother’s milk. Immunoglobulins are the antibodies that recognize a pathogen and attach to it to mark it for destruction by other cells. The immunoglobulins in human milk and in cow’s milk help protect the newborn from gastrointestinal infection and inflammation. Cytokines are protein hormones produced by numerous types of cells. These molecules mediate and regulate the inflammatory responses that are associated with the immune response. It takes over a year for an infant to develop a mature immune system. Until then, the immunoglobulins and cytokines present, first, in mother’s milk and, later, in cow’s milk (when it is added to the child’s diet), protect the infant and young child from infections.
3. **“The milk carton says the milk is pasteurized. Is that the same as homogenized?”** Pasteurization and homogenization are not the same thing. Pasteurization is a heat process invented by the French scientist Louis Pasteur in 1864 to kill the bacteria that was spoiling wine and beer. The process was soon applied to milk as well. During pasteurization milk is heated to 162 °F for 15 seconds, killing most of the bacteria present. Pasteurized milk needs to be refrigerated and has a shelf life of 2–3 weeks. Milk that has been heated to 280 °F for 2 seconds is ultra-pasteurized and has a non-refrigerated shelf life of nine months. Milk is generally pasteurized before it is homogenized. Homogenization is a mechanical process, where milk under pressure is forced through a very fine screen, breaking the milk fat into smaller particles that remain evenly suspended in the milk rather than separate out.
4. **“Besides milk, what are some other examples of emulsions?”** An emulsion is a dispersion of one liquid into another liquid, which normally do not mix. Examples besides milk are

* butter—a mix of water and fat
* mayonnaise—a mix of oil and vinegar with egg yolk as the emulsifying agent
* crema on espresso—a dispersion of water and coffee oil

1. **“Do the micelles contain anything other than calcium phosphate in their middles? How does the calcium get out?”** The micelles’ chief biological function is to carry large amounts of highly-insoluble calcium phosphate to mammalian young. They are porous structures and hold a considerable amount of water or milk serum. They also contain citrate, minor ions, and lipase and plasmin enzymes. In an acidic environment such as the stomach, the casein micelles are denatured and their contents released.
2. **“My sister is lactose intolerant. Do any of the plant-based milks contain lactose?”** None of the plant-based milks contain lactose. Lactose is a disaccharide sugar specifically found in animal milk. It is composed of the monosaccharides glucose and galactose. The enzyme lactase (which is often missing in people who are lactose intolerant) reduces lactose to glucose and galactose, which can then be absorbed through the intestine. When lactose does not get broken down, it can ferment in the large intestine, leading to bloating and abdominal discomfort.
3. **“What are isoflavones? How do they protect against cardiovascular disease and osteoporosis?”** Isoflavones are compounds derived from plants that are referred to as phytoestrogens because they can weakly act like estrogen. Estrogen has many functions in the body, one of them related to bone health. It protects against bone loss by preventing the bones from losing calcium. As women age, they produce less estrogen and are susceptible to osteoporosis. Adding soy isoflavones to the diet can result in up to a 7.6% increase in bone calcium retention. Isoflavones also have antioxidant properties and, as such, can promote good heart health. They prevent the buildup of arterial plaques (lipid deposits on the lining of the arteries) by preventing the oxidation of LDLs (low-density lipoproteins).
4. **“What is lauric acid and how does it affect my brain?”** Lauric acid is a medium-chain (C12) fatty acid that is 5.5% of the fat found in human breast milk and is also in some plant oils. Lauric acid, shown to have antibacterial and antiviral properties, is present in coconut milk and in coconut oil. Because of its shorter carbon chain, it can be absorbed into the bloodstream quickly, providing the fuel for energy, like a carbohydrate, but without the sugar spike. Lauric acid is metabolized into ketones that can be used by the brain for energy in place of glucose. In the brains of patients with Alzheimer’s disease, where the neurons seem to suffer an energy deficiency, the increased availability of ketones has been shown to improve neuron function. While coconut milk is a good source of lauric acid, it also has a higher overall fat content than the other milks and zero protein.
5. **“Which milk overall is best for human health?”** The gold standard among kinds of milk is still cow’s milk. Dietitian and nutrition specialist Amy Goodson states, “When looking for vitamins, minerals, protein, and a lower cost, cow’s milk is your best option. Cow’s milk contains 1 gram of protein per ounce, or 8 grams for 1 cup. The other milks don’t measure up, protein-wise, with 0–1 grams for 1 cup (8 ounces).” Soy milk contains a similar nutrient profile for vegans or those who are lactose intolerant.   
   (<https://aaptiv.com/magazine/milk-varieties-101>)

### Activities

**Labs and demos**

**“Salad Dressing Science: Emulsions” lab:** Students use different substances as emulsifiers in salad dressing. The materials include background information on hydrophobic and hydrophilic concepts and how emulsifiers bring these two different molecules together. (Access is restricted to AACT members, but the article will be available for free until April 1, 2019, at <https://teachchemistry.org/classroom-resources/salad-dressing-science-emulsions>.)

**“Analyzing Mixtures” demonstration:** While introducing the concepts of heterogeneous and homogeneous solutions and emulsions, the teacher creates a sequence of mixtures with water, oil, food coloring, and soap in a single test tube. (Access is restricted to AACT members, but the article will be available for free until April 1, 2019, at <https://teachchemistry.org/classroom-resources/analyzing-mixtures>.)

**Simulations**

**“Miscibility of Liquids”:** In this simulation, students can mix water and oil; water and alcohol; and water, alcohol, and oil to observe which liquids are miscible or immiscible. (<http://www.physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/miscibility_of_liquids.htm>)

**Media**

**“Are Milk Substitutes Healthier than Cow’s Milk?” (4:14 video):** The moderator in this British video compares dairy milk to soy and almond milks in terms of protein, calcium, vitamin D, and iodine content. She also discusses the chemistry surrounding lactose intolerance. (<https://www.youtube.com/watch?v=TUpQpWxMYtk>)

**“Milk Minus Moo: A Look at Milk Alternatives” (4:16 video):** In this *Today Show* video segment, a nutritionist reviews alternative milks—almond, hemp, coconut, rice, and soy. Besides the nutritional content of each product, she also discusses their best uses. (<https://www.today.com/video/milk-minus-moo-a-look-at-milk-alternatives-44510787759>)

**Lessons and lesson plans**

**“What Type of Mixture is Paint?”:** This lesson presents solutions, suspensions, and colloids, with a scheme for identifying each one. The lesson has an inquiry component where the students design their own paint from a variety of teacher supplied materials and then test the paint to determine what type of mixture they have created. (Access is restricted to AACT members, but the article will be available for free until April 1, 2019, at <https://teachchemistry.org/classroom-resources/what-type-of-mixture-is-paint>.)

“**Solutions, Suspensions, Colloids”:** In this lesson students make a variety of mixtures, observe and test them, and then classify them as solutions, suspensions, or colloids. Making mayonnaise is an extension activity placed at the end of the lesson. <https://www.woodstown.org/cms/lib4/NJ01001783/Centricity/Domain/8/Texts/ACS/resources/ac/ch6/act3.pdf>

**Projects and extension activities**

**“Magic Milk”:** Students add detergent to a mixture of milk and food coloring and then attempt to explain their observations. The activity could be done with the different milk alternatives to see how their reactions compare with those in whole milk and, as an extension, students could be tasked with explaining what is happening on a molecular level, accompanying their explanation with particle drawings. (Access is restricted to AACT members, but the article will be available for free until April 1, 2019, at <https://teachchemistry.org/classroom-resources/magic-milk>.)

A video of this lab can be found here: <https://www.stevespanglerscience.com/lab/experiments/milk-color-explosion/>.

The graphics in the explanation of this activity at the site below could be used as an example of using particle drawings to illustrate an explanation. <https://www.acs.org/content/acs/en/education/whatischemistry/adventures-in-chemistry/experiments/colors-move.html>

**“Milk Posters” project:** Students working individually or in groups could be assigned a type of milk or milk alternative to research and make a poster presentation of the pros and cons associated with their assigned milk. They should include the caloric value and nutrient values on their poster, as well as the health benefits of the milk and the persons that would be most attracted to their product.

### References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles and Teacher’s Guides published from the first issue in October 1983 through April 2013.**

**The DVD is available from the ACS for $42 ($135 for a site/ school license) here:** [***http://www.acs.org/chemmatters***](http://www.acs.org/chemmatters)***.***



In “Yogurt”, author Evans presents the history of yogurt and discusses the casein micelles’ role, as well as that of bacteria in the formation of yogurt. (Evans. G. D. Yogurt. *ChemMatters*. 1989, *7* (3), pp 9–12)

“Poisoned Milk” is an interesting story about how chemists solved the mystery of why thousands of pioneers died after drinking cow’s milk. Cows that eat the white snakeroot weed produce toxic milk. (Plummer. C. M. Poisoned Milk. *ChemMatters*. 1992, *10* (4), pp 10–13)

The article “Say Cheese” contains a good discussion of milk components, including casein micelles, which separate out during cheese formation. A recipe for making lemon cheese in class is given at the end of the article. (Baxter, R. Say Cheese. *ChemMatters*. 1995, *13* (1), pp 4–7)

Author Baxter discusses the chemistry of ice cream, including a discussion about colloids and emulsions. She includes a recipe for making ice cream within the article. (Baxter. R. Making Ice Cream: Cool Chemistry. *ChemMatters*. 1995, *13* (4), pp 4–7)

The Teacher’s Guide for the December 1995 *ChemMatters* article above provides additional instructions for making several variations of ice cream in class.

In “Hold the Meat! Meat-free Food Takes a Seat at the Table”, author Nolte includes information about complete proteins and protein chemistry, while discussing food products made from soy milk. (Nolte. B. Hold the Meat! Meat-free Food Takes a Seat at the Table. *ChemMatters*. 2011, *29* (4), pp 9–11)

“Who Put the Cheddar in Cheese?” contains a discussion about milk as a colloid, as well as the concept of diffusion in the salting process in cheese production. (DeAntonis. K. Who Put the Cheddar in Cheese? *ChemMatters*. 2012, *30* (1), pp 12–13)

In “Ice Cream … And Chemistry”, author Rohrig describes ice cream as an emulsion and discusses the components of milk that act as emulsifiers. (Rohrig. B. Ice Cream … And Chemistry. *ChemMatters*. 2014, *32* (1), pp 6–9)

“The Protein Myth: Getting the Right Balance” contains information about the nine essential amino acids that are required for complete protein sources, as well as protein synthesis. (Tyrell. K. The Protein Myth: Getting the Right Balance. *ChemMatters*. 2018, *36* (2), pp 5–7)

The Teacher’s Guide for the April 2018 *ChemMatters* article above contains a lesson about isolating and testing milk proteins that could be adapted to use with milk alternatives.

### Web Resources for More Information

**Milk alternatives, almond, soy, rice, and coconut**

“Comparing Milks: Almond, Dairy, Soy, Rice, and Coconut” describes each milk, summarizes their pros and cons, and displays the comparative nutrient profiles in table format.

(<https://www.healthline.com/health/milk-almond-cow-soy-rice>)

“Dairy Milk Substitutes: Soy, almond, and others” discusses the nutrient profile of each milk substitute, as well as their pros and cons. Links to related articles is an added bonus.

(<https://www.medicalnewstoday.com/articles/273982.php>)

**Other non-dairy milk alternatives**

“The Best and Worst Milks and Milk Substitute Types” analyzes the pros and cons of several alternative milk products and gives recommendations for a specific brand of each one.

(<https://www.eatthis.com/best-worst-milk-alternatives/>)

The pros and cons of several nut-free, non-dairy milk alternatives are discussed at this site.

(<https://www.thekitchn.com/nut-free-non-dairy-milk-256963>)

**Soy isoflavones**

“The Healing Power of Soy’s Isoflavones” discusses the many health benefits derived from a diet rich in soy.

(<https://www.fwhc.org/health/soy.htm>)

A number of scientific articles about isoflavones and their application to a variety of medical conditions can be found at this site.

(<https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/isoflavones>)

**Coconut milk and lauric acid**

In “Lauric acid-rich medium-chain triglycerides can substitute for other oils in cooking applications and may have limited pathogenicity”, the author presents the chemistry of lauric acid metabolism and the effects of the resulting ketones on the brain and body.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4975867/>)

“The Health Benefits of Coconut Milk” briefly explains the benefits of the medium-chain fatty acids like lauric acid that are found in coconut milk.

(<https://www.bbcgoodfood.com/howto/guide/ingredient-focus-coconut-milk>)

**Casein micelles**

This site includes more in-depth information about casein micelles.

(<https://www.uoguelph.ca/foodscience/book-page/structure-casein-micelle>)

Information about the composition of the milk proteins casein and whey can be found at this site.

(<http://ansci.illinois.edu/static/ansc438/Milkcompsynth/milkcomp_protein.html>)

**Hormones in milk**

“How does dairy affect your hormone levels?” discusses the hormones naturally occurring in milk and how they affect your own hormone levels.

(<https://www.quickanddirtytips.com/health-fitness/womens-health/how-does-dairy-affect-your-hormone-levels>)

In “Hormones: What’s in your Milk?” the author includes a table of the origins of the hormones that are present in cow’s milk and provides information about the hormones.

(<http://igrow.org/livestock/dairy/hormones-whats-in-your-milk/>)

**Mixtures chemistry**

This source contains multiple links where students can find additional information on chemistry topics related to mixtures.

(<https://www.thoughtco.com/solutions-suspensions-colloids-and-dispersions-608177>)

In the short article “Colloid Chemistry in the Coffee Shop”, the author presents the chemistry concepts of colloids, solutions, and emulsions while discussing the composition of different coffees and even donuts.

(<https://eic.rsc.org/opinion/colloid-chemistry-at-the-coffee-shop/2020990.article>)

**Immunoglobulins and cytokines**

“Effects of Bovine Immunoglobulins on Immune Function, Allergy, and Infection” reports on the research into the effect of bovine immunoglobulins from milk on human infants.

(<https://www.frontiersin.org/articles/10.3389/fnut.2018.00052/full>)

“Cytokines in Human Milk” presents information on the role of cytokines in mediating the immune response to pathogens.

(<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.603.7183&rep=rep1&type=pdf>)

**Homogenization and pasteurization**

“Pasteurized vs Homogenized Milk: What’s the Difference?” explains the pasteurization and homogenization processes used by the milk industry.

(<https://www.huffpost.com/entry/pasteurized-homogenized-milk_n_5606168>)

**Dairy milk vs nut and seed milks (Oh, the politics!)**

“Nut Milks are Milk Says Almost Every Culture across the Globe” exposes students to the culture and politics surrounding the dairy milk industry vs the nut milk industries.

(<https://www.smithsonianmag.com/history/nut-milks-are-milk-says-almost-every-culture-across-globe-180970008/>)

### *Reading Supports*

The pages that follow include reading supports in the form of an Anticipation Guide, Reading Strategies, 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.

* **Anticipation Guide (page 15):** 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.

**Or** consider the following ideas to engage your students in reading:

**Making Sense of Milk**

* Before reading, ask students if they drink milk other than cow’s milk, and why. Ask them what questions they might have about the differences in cow’s milk and plant-based milks.
* As they read the article, students should look for answers to their questions.
* **Graphic Organizer (page 16):** 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 (pages 17, 18):** 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.

Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.

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. The “Web Resources for More Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

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. Plant-based beverages have been used for centuries. |
|  |  | 1. The nutritional purpose of cow’s milk is similar in some ways to that of nuts. |
|  |  | 1. Homogenized milk is a mixture containing small suspended fat particles. |
|  |  | 1. Most proteins in cow’s milk are soluble in water. |
|  |  | 1. Plant-based milks are suspensions. |
|  |  | 1. Dairy products are excellent sources of minerals needed for bone health. |
|  |  | 1. No plant-based milks are high in protein. |
|  |  | 1. Almond milk is high in saturated fat. |
|  |  | 1. Milk allergies are caused by proteins. |
|  |  | 1. There is not much difference between botanical milks and cow’s milk. |

### Graphic Organizer

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Types of Proteins** | **Minerals** | **Vitamins** | **Fat content** |
| **Cow’s milk** |  |  |  |  |
| **Soy milk** |  |  |  |  |
| **Almond milk** |  |  |  |  |
| **Rice milk** |  |  |  |  |
| **Coconut milk** |  |  |  |  |

**Directions**: As you read, complete the graphic organizer below to compare cow’s milk to plant-based milks.

**Summary:** On the back of this paper, write one or two sentences describing which type of milk you choose to drink, and why, using information from the article.

### Student Reading Comprehension Questions

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

Name

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

* 1. How does the nutritional purpose of animal milk resemble that of nuts and seeds?
  2. How can milk be both a solution and a suspension?
  3. What is homogenization?
  4. Describe the structure and composition of micelles in milk.
  5. Explain how milk can be classified as a colloid.
  6. Name the sources of the four most widely-available plant-based milk alternatives?

**Student Reading Comprehension Questions, cont.**

* 1. What do nutritionists look at when they are evaluating protein quality?
  2. Besides protein, calcium, potassium, and vitamin D, what seven nutrients are contained in cow’s milk that are not always contained in plant-based milk alternatives?
  3. Compare the nutrient content of each of the four main plant-based kinds of milk to that of cow’s milk.
  4. What are the potential health effects of (a) soy milk, (b) almond milk, and (c) coconut milk?

**Critical-Thinking Questions**

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

* 1. What type of milk would be the best choice for a distance runner or swimmer prior to their competition? Explain your choice.
  2. Explain how (a) skim milk and (b) 2% milk could be made from unhomogenized whole milk. (Whole milk is approximately 3.5% milkfat, depending on the cow—Holsteins, the black and white cows, produce milk with lower fat (cream) content, while Jerseys, the light-brown cows, produce milk with higher fat (cream) content.)

### Answers to Reading Comprehension Questions

1. **How does the nutritional purpose of animal milk resemble that of nuts and seeds?**

The nutritional purpose of animal milk is to feed young animals, while plant seeds provide nutrients for embryonic plants to use to develop into seedlings.

1. **How can milk be both a solution and a suspension?**

Milk is a solution because the sugars and minerals in milk are dissolved in the watery portion of milk, while the lipids in milk form small clumps of fat that stay suspended in the watery base in store-bought milk.

1. **What is homogenization?**

Homogenization is the mechanical process that breaks up larger particles of fat into smaller particles so that they will stay suspended in the watery mixture.

1. **Describe the structure and composition of micelles in milk.**

The micelles in milk are spherical casein protein particles that have a hydrophilic, or “water-loving”, side that faces outward and a hydrophobic, or “water-hating”, side that gets tucked inside the sphere along with clusters of calcium phosphate.

1. **Explain how milk can be classified as a colloid.**

Milk can be classified as a colloid because of the droplets of fat and protein that are dispersed and suspended in the watery mixture.

1. **Name the sources of the four most widely-available plant-based milk alternatives.**

The sources of the four widely-available plant-based milk alternatives are

1. soy,
2. rice,
3. almonds, and
4. coconuts.
5. **What do nutritionists look at when they are evaluating protein quality?**

When evaluating protein quality, nutritionists look at the amino acid composition, digestibility, and how much of the protein the body can use—its bioavailability.

1. **Besides protein, calcium, potassium, and vitamin D what seven nutrients are contained in cow’s milk that are not always contained in plant-based milk alternatives?**

The seven nutrients that are found in cow’s milk that are not always contained in plant-based milk alternatives are phosphorus, zinc, thiamin, vitamin B6, vitamin E, vitamin K, and folate.

1. **Compare the nutrient content of each of the four main plant-based kinds of milk to that of cow’s milk.**
   1. Soy milk is the closest in nutrient content to that of cow’s milk. It contains the nine essential amino acids that the human body can’t synthesize, so it is a complete protein source like cow’s milk. It is often fortified with B vitamins, vitamin D, and calcium.
   2. Almond milk is low in protein but has a high vitamin E content and does not contain saturated fats. It can be fortified with other nutrients that are found in cow’s milk.
   3. Rice milk is low in protein and high in carbohydrates. It is often suggested for individuals with multiple allergies.
   4. Coconut milk is a good source of potassium and contains iron and fiber but it is low in protein and has a higher saturated fat content than the other plant-based milks.
2. **What are the potential health effects of (a) soy milk, (b) almond milk, and (c) coconut milk?**
3. “Soy milk contains isoflavones that some research suggests can protect against cardiovascular disease and osteoporosis.”
4. Almond milk contains antioxidants and vitamin E that can guard against cellular damage.
5. “Coconut milk contains lauric acid, which some research suggests promotes brain development and helps boost the immune system.”

**Critical-Thinking Questions**

1. **What type of milk would be the best choice for a distance runner or swimmer prior to their competition? Explain your choice.**

Rice milk would be the best choice for a distance runner or swimmer because of its high carbohydrate content. An athlete that participates in an endurance sport such as distance running or swimming needs stored energy to improve their performance. Carbohydrates from the diet are stored as glycogen in the muscles and in the liver. Endurance athletes need to make sure they get enough carbohydrates in their diet to ensure that they will have adequate amounts of glycogen stored in their bodies in order to have enough energy to finish their races.

1. **Explain how (a) skim milk and (b) 2% milk could be made from unhomogenized, whole milk. (Whole milk is approximately 3.5% milkfat, depending on the cow—Holsteins, the black and white cows, produce milk with lower fat (cream) content, while Jerseys, the light-brown cows, produce milk with higher fat (cream) content.)**

Possible Student Answer

Since fat is less dense than the watery portion of milk, it will rise to the top and form a fat layer (the cream). This layer should be removed and set aside, and the remaining watery portion below it would be the skim milk.

To make 2% milk, weigh a quantity of the skimmed milk. Calculate 2% of this weight to determine the weight of fat removed in (a) above to be added back into the milk in order to make milk that is 2% milkfat. Weigh out the calculated amount of cream and then add it to the weighed skim milk.



**Teacher's Guide for**

### *“What’s Sunless Tanner?”*

**February/March 2019**

**Table of Contents**

[Tools and Resources 23](#_Toc523845025)

[Connections to Chemistry Concepts 23](#_Toc523845026)

[Possible Student Misconceptions 24](#_Toc523845028)

[Anticipating Student Questions 26](#_Toc523845029)

[Activities 27](#_Toc523845030)

[References 29](#_Toc523845031)

[Web Resources for More Information 30](#_Toc523845032)

[*Reading Supports* *32*](#_Toc523845033)

[Anticipation Guide 34](#_Toc523845034)

[Graphic Organizer 35](#_Toc523845035)

[Student Reading Comprehension Questions 36](#_Toc523845036)

[Answers to Reading Comprehension Questions 38](#_Toc523845037)

### *Tools and Resources*

### Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Organic nomenclature** | When students study basic organic nomenclature, they often want to know how to read and understand the active ingredients listed on prescription and over-the-counter medicines. This article provides an opportunity for a student challenge: dissect the name of the compound dihydroxyacetone. |
| **pH** | As students study pH, information in this article refers to the importance of adjusting the pH to stabilize molecules such as dihydroxyacetone. |
| **Chemical reactions** | Information in this article brings chemical reactions into the real world for students who may not realize that the same chemical reaction, Maillard, can brown both food (toast) and skin (tan). |
| **Scientific process** | When introducing students to scientific processes, the use of Dr. Wittgenstein’s serendipitous discovery of the chemical in vomit that led to sunless tanning preparations presents a great example of how scientists work. The excitement of this “find” may encourage students to look for patterns and then test their own inferences. |
| **Electromagnetic spectrum** | The study of the electromagnetic spectrum is usually accompanied by high student interest in the waves that are most relevant to their lives: microwaves feed them and UV radiation tans them (and causes cancer). This article provides a good place in the curriculum to introduce the possibility of safer tanning procedures. |
| **Risk/Benefit** | Articles like this can help to prevent or help to mitigate (possibly even cure?) “chemophobia”. Providing both the benefits and the risks associated with specific chemicals can help students understand that chemistry is not something to be feared, but something to be understood and appreciated. |

### Possible Student Misconceptions

1. **“I’ve heard that sunless tanning sprays prevent sunburns.”** No, sunless tanning sprays or creams do not prevent sunburns. Sunless tanning solutions contain a sugar such as dihydroxyacetone that reacts with the amino acids in dead skin. These cells, located on the upper surface of your skin, temporarily darken by the Maillard reaction to form a simulated tan. Sunless tanners do not protect the inner skin cells from UV radiation that can cause skin cancer and burn the skin.
2. **“I’ll always use sunless tanners that contain sunscreens to prevent burning.”** This sounds like a good idea; however, the American Academy of Dermatology suggests that to be safe you need to apply sunscreen every 2–3 hours; your sunless tanner works for 4–7 days, so it will far outlast the safety of its sunscreen. Unless you decide to stay indoors (at the Prom for example) with your new tan, you will need to severely restrict your time in the sun to the first 2–3 hours after tanning.
3. **“Good sunless tanners produce nice, even tans that should shield and protect my skin from burning, just like a suntan.”** No matter how even your tanner appears, it only reacts with the amino acids in the outer layer of dead skin cells. This provides no protection from UV radiation. UV rays penetrate the outer layers of the skin and trigger inner skin cells, melanocytes, to produce melanin, the brown pigment that causes tanning and helps protect skin from burning.
4. **“They say that using spray tanners is the best way to receive an even, sunless tan. And, you can do this yourself safely at home.”** Do-it-yourself sunless spray tanning can be dangerous at home. If you inhale the fumes, you run the risk of pulmonary disease or cancer. Moreover, the spray is only U.S. FDA-approved for your skin. Exposure to the spray on your eyes, lips or mucous membranes could cause severe headaches, nausea, or dizziness, and some think that in the bloodstream it could lead to cancer. Experts suggest that spray tanning should be done in a salon while wearing goggles.
5. **“I’m going to gradually build up my natural suntan to prevent skin cancer.”** Research shows that, while gradually building up natural suntans may help prevent sunburn, the suntan is evidence that the UV rays are also damaging the skin, possibly resulting in premature wrinkles and dark spots. In addition, the UV rays may cause oxidative damage to DNA in the deep-skin stem cells, leading to skin cancer.
6. **“My skin is naturally brown rather than tanned, so I don’t have to worry about getting a sunburn.”** Sorry, but no one is immune. Skin cancers such as melanoma can still occur in people who have darker skin pigmentation, so wear sunscreen and clothing that protects you from the sun’s UV radiation.
7. **“I’m very careful to go inside if my skin just gets a little pink or red, because I don’t want a real sunburn.”** Pink or red means that your skin has been burned. Your skin doesn’t need to blister, peel or become raw to indicate damage (mutations) to the DNA of your inner skin cells.
8. **“I don’t understand how the Maillard reaction can occur in bread since it doesn’t contain DNA.”** Bread *does* contain DNA; the bread wheat genome contains approximately five times more DNA than the human genome. Human chromosomes have two sets of chromosomes; wheat has six. Most of the wheat DNA is composed of repetitive sequences interwoven to form a dense, complicated genome composed of many base pairs. Bread also contains carbohydrates (sugars) that combine with the amino acids in wheat DNA; the Maillard reaction occurs when initiated by the heat in the toaster.

### Anticipating Student Questions

1. **“What was the rare metabolic disease that Dr. Wittgenstein was treating in children when she discovered the tanning effects of dihydroxyacetone?”**Dr. Wittgenstein was treating children who had glycogen storage disease. This is a metabolic disorder caused by the lack of enzymes that regulate the synthesis and degradation of glycogen in the body. Glycogen is a polysaccharide form of glucose, the form that is stored as energy in humans, animals, fungi, and bacteria.
2. **“The names sound familiar, so are melanoidins related to melanin?”** Yes, melanoidins are pigments formed when dihydroxyacetone reacts with amino acids to form a sunless tan (the Maillard reaction). This reaction occurs in the outer layers of your skin and does not offer protection from the damage caused by UV rays.Melanin is the natural coloring pigment located in deep layers of your skin that provides limited protection for your skin from UV radiation.
3. **“Why do sunless tanners only last 3**–**10 days?”** Everyone’s skin cycle is different, but most outer skin sheds every 3–10 days, these outer dead skin cells are the ones that have been “tanned” by sunless tanners. So the sunless tan will fade as the outer dead skin cells replace themselves with new untanned skin cells.
4. **“How long does it take for a tan to be produced by a sunless tanner spray or solution?”** The sunless tanning process takes approximately 6–10 hours for the full tan to develop. For the best results, do not shower, sweat profusely, or wash off the tan during this time.
5. **“What happens in your skin to produce a natural tan?”** A natural suntan is the body’s protective response to UV exposure. In an effort to protect the skin from burning, UV rays interact with DNA to initiate a response that signals deep skin cells to produce more of the tan-colored pigment melanin.
6. **“How much skin protection does a natural tan provide?”** A natural base tan only provides a Sun Protection Factor (SPF)of 3 or less; the American Dermatology Association recommends a sunscreen or clothing with SPF 30 or more.
7. **“Are there any dangers involved in the use of sunless tanners?”** As long as you a) recognize that your fake tan offers no protection from the sun’s UV rays, b) use sunscreen and/or UV protective clothing, and c) do not inhale or expose your lips, eyes and mucous membranes to the tanner, no dangers have been specifically identified and the products are deemed safe by the U.S. FDA. The primary downside is that, to maintain your tan, you will have to reapply the solution every 4–7 days.
8. **“What is the relationship between a suntan and a sunburn and why do they occur?”** The body naturally tries to defend itself against damaging UV rays. At first, the inner skin cells receive a signal to produce more melanin, which tans your skin. Then as you remain in the sun, this system is overwhelmed by the UV rays, causing inner-skin-cell DNA mutations, plus burning and blistering of the skin.

### Activities

**Labs and demos**

**“The Most Effective Sunscreen” MS/HS Lab (60 min):** During this AACT lab, students will test the amount of UV protection provided by various sunscreens as measured by UV bead detectors. Complete student instructions are provided, and there are additional resources for the teacher. (Access is restricted to AACT members, but the article will be available for free until February 1, 2019, at <https://teachchemistry.org/classroom-resources/the-most-effective-sunscreen>)

**“The Maillard Reaction” demo or student lab from video (3:59):** This video shows how the Maillard reaction can be tested in test tubes heated in a water bath. The set-up is clearly demonstrated and could be repeated easily as a demo or a student mini-lab. (<https://www.youtube.com/watch?v=SLAz3oiMi8Q>)

**Media**

**“What is the Maillard Reaction?” video (2:10):** This brief *Scientific American* video discusses the Maillard reaction and explains how thousands of flavor compounds can be produced by using proper cooking temperatures to react various sugar and amino acid combinations. (<https://www.youtube.com/watch?v=c7WI41huAok>)

**“The Maillard Reaction” video (3:01):** This video shows the process of roasting (caramelizing) coffee beans and how the length of time spent in the Maillard phase determines the strength of the coffee. A long period of time produces molecules of high molecular weight in the beans, which forms a more viscous, darker cup of coffee; hence, “dark roast”.

(<https://www.youtube.com/watch?v=9gASsB1AeC8>)

**Lessons and lesson plans**

**“Sun & Skin” research lesson for grades 9**–**12 (several days):** In this AAAS lesson, students work in groups to answer research questions that apply to a virtual scenario (a beach vacation). Appropriate links are provided for students to study the impact of UV radiation and ways to protect the skin; the lesson contains links, questions, discussion, and suggestions for a final summary activity. (<http://sciencenetlinks.com/lessons/sun-skin/>)

**“UV Light Detecting Beads” chemistry lesson:** This lesson contains a variety of hands-on ways to explore UV radiation; it introduces the electromagnetic spectrum and the wavelengths of UV, the chemistry of UV beads, and it provides several relevant classroom activities and extensions, such as UV-sensitive silly putty and fingernail polish. (<http://cdn.teachersource.com/downloads/lesson_pdf/UV-AST.pdf>)

**Projects and extension activities**

**“Chemistry Sandwiches” grades 11**–**12 chemistry take-home project (90:00):** This project (developed with NSF funding for the MS state lesson plans) involves kitchen cooking, so it must be done under proper parent/guardian supervision; students will study several chemical reactions including the Maillard reaction as they make and bake bread, brown meat, and caramelize peppers and onions to make a sandwich. (<https://www.gk12.msstate.edu/lessonplans/272_INSPIRE_LP_mclaurin_020112.pdf>)

**“Chemistry of Summer”, 3 videos (2**–**3 min. each), 15 questions/experimental design suggestions:** all contained within the site,excellent material from an ACS ChemClubs publication. <https://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/summer.html>) (This lesson is available free at this URL.)

* **“How Sunless Tanners Work: Tan in a Can Chemistry” Bytesize Science (2:50):** Describes Dr. Wittgenstein’s discovery and explains how sunless tanners work.(<https://youtu.be/qP22ODuCip4>)
* **“Repelling the Rays: Chemistry of Sunscreens” Bytesize Science (3:39):** Explains UV radiation and how sunscreens work. (<https://youtu.be/wopwVVsbvWI>)
* **“Sunscreen SPF explained—Speaking of Chemistry” ACS *Chemical and Engineering News* (2:52):** Explains SPF in sunscreens. (<https://www.youtube.com/watch?v=pXR5F6mYal0>)
* Many of the 15 questions for students to consider suggest experimental designs to test their ideas.

The three videos above with individual URLs are located inside the lesson and accessed by the menu located in the upper left corner of the video screen shown in the lesson.

### References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles and Teacher’s Guides published from the first issue in October 1983 through April 2013.**

**The DVD is available from the ACS for $42 ($135 for a site/ school license) here:** [***http://www.acs.org/chemmatters***](http://www.acs.org/chemmatters)***.***



“Sun Alert” contains a good illustration and description of the layers of human skin, plus a table showing the effects of UV radiation (A, B, and C) on the skin; calculation of SPF rating for sunscreens; and the concern about indoor tanning salons that advertise their process as absolutely safe (disputed by the U.S. FDA). (Baxter, R. Sun Alert. *ChemMatters*. 1998, *16* (2), pp 4–6)

“Open for Discussion: A Tan—Quick, Easy, and Safe?” discusses the safety of various tanning options including outdoor sun, tanning beds, and sunless products; the electromagnetic spectrum, UV radiation, and dihydroxyacetone are also discussed in this one-page article. (Sitzman, B. and Goode, R. A Tan—Quick, Easy, and Safe? *ChemMatters*. 2012, *30* (1), p 5)

“Two Is Better than One” explains why toast tastes better if toasted twice, first to evaporate the water and then a second time to undergo the Maillard reaction; a nice infographic shows the Maillard reaction and explains the chemistry that occurs while food browns. (Husband, T. Two Is Better than One. *ChemMatters*. 2012, *30* (4), pp 9–11)

The Teacher’s Guide for the December 2012 *ChemMatters* article above provides additional information about the chemistry behind the Maillard reaction and includes several resources from food chemistry.

The Teacher’s Guide for the April 2013 *ChemMatters* barbecue article uses a diagram to describe the Maillard reaction between glucose and an amino acid to form melanoidins; an unpleasant effect of the Maillard reaction: proteins and sugars in the lens of an aging eye are highly susceptible to forming cataracts and causing macular degeneration and diabetic retinopathy when they undergo the Maillard reaction; the products of this reaction form aggregates that scatter light and impede vision.

### Web Resources for More Information

**Structure of human skin**

This article contains a good diagram and description of the three layers of the skin, accompanied by a description and the location of common skin cancers (melanoma, basal cell carcinoma, squamous cell carcinoma).

(<https://www.webmd.com/skin-problems-and-treatments/picture-of-the-skin#1>)

“UV Radiation and the Skin” is an excellent research paper that contains a detailed diagram of the epidermis, with a description of the functions of each layer. UV radiation’s effects on human health are discussed as complex.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3709783/>)

**Maillard reaction**

“The Accidental Scientist” article explains the initial discovery by Louis-Camille Maillard early in the early twentieth century. The accidental discovery by World War II soldiers—that when powdered, dehydrated eggs were browned, the result was very distasteful—led to understanding the chemistry of the earlier Maillard discovery.

(<https://www.exploratoriumedu/cooking/meat/INT-what-makes-flavor.html>)

This article begins with an excellent infographic showing the non-enzymatic (without enzymes) guide to the Maillard reaction, including a list of some of the classes of products. History of discovery and development of the mechanism is given along with information about the importance of pH and temperature.

(<https://exploratorium.edu/cooking/meat/INT-what-makes-flavor.html>)

**Risks/Risky behavior**

Increased rates of melanoma in young people living in southern beach communities led researcher Natalie R. Gassman, University of Southern Alabama Mitchell Cancer Institute, to study intentional tanning practices of high school and college students, including outdoor, indoor, and spray-tanning practices. The paper “Intentional tanning behaviors among undergraduates on the United States’ Gulf Coasts” includes research protocols and statistical analysis, with a discussion of findings.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5883533/>)

“Sunless Tan Doesn't Take Away Risk of Cancer” was published in *Medical Daily*, a medical and nutritional news website, published by *Newsweek* magazine. The article quotes a study from the University of Minnesota showing that young adults who use sunless tanners are in danger of developing skin cancers because they frequently engage in risky outside behaviors such as declining to seek shade, use sunscreens, or wear UV protective clothing.

(<https://www.medicaldaily.com/sunless-tan-doesnt-take-away-risk-cancer-426537>)

**Dermatologystudies**

A survey published in the *American Academy of Dermatology* discusses survey results from young adults that indicate a large percentage of them lack understanding of the consequences of tanning—and few of them care. The article recommends self-tanning over UV exposure, provides instructions on how best to apply sunless products, and includes warnings about the need for sunscreen to accompany them.

(<https://www.aad.org/media/news-releases/dermatologists-give-young-adults-something-to-tweet-about-tanning-s-out>)

This paper, published in the *Journal of Clinical and Aesthetic Dermatology,* reviews methods of tanning used today; the forms of skin cancer related to types of UV radiation; and the side effects of dihydroxyacetone tanners, particularly those in spray form. While once thought to react with only the dead outer layer of skin cells, current research shows that, when used constantly, as much as 11% of the dihydroxyacetone penetrates deeply into the epidermis and dermis skin layers.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4345932/>)

**Fake tan infographic**

The infographic “The Chemistry of Fake Tan” shows structural formulas of dihydroxyacetone and erythrulose (often used in combination with dihydroxyacetone), two sugars that react with amino acids to form tans; it provides a description of the chemistry involved in the ”fake” tanning process and provides information about the potential risks of sunless tanning.

(<https://www.compoundchem.com/2014/08/07/faketan/>)

Erythrulose (shown in the infographic above), found naturally in red raspberries, is a sugar with a structure similar to dihydroxyacetone, except that it is a tetrose carbohydrate that contains a ketone group (C4H2O4), so it reacts with amino acids in proteins of the outer layer of dead skin cells; while not approved by the U.S. FDA, it is often used with dihydroxyacetone to produce a longer tan.

(<https://en.wikipedia.org/wiki/Erythrulose>)

**Research studies**

University of Minnesota researchers concerned with the increase in melanoma skin cancer in the U.S. interviewed 27,000 sunless tanners, men and women 18 years or older, to determine their potential for behavior that could increase the risk of skin cancer. They found that the use of sunless tanners was associated with risky sun cancer behaviors such as failure to use sun protection (clothing or lotions); results of their study were published in the *Journal of the American Medical Association* (JAMA).

(<https://www.ncbi.nlm.nih.gov/pubmed/30046802>) (Abstract available here full text available with subscription or free personal account.)

The increasing incidence of skin cancer has led to the demand for safer tanning methods and to studies such as those reviewed in “A Review of Common Tanning Methods” published by *The Journal of Clinical and Aesthetic Dermatology*. In this article, various forms of skin cancer due to exposure to UVA or UVB radiation outdoors or at inside tanning bed salons are described, plus the research involving the use of over-the-counter topical sunless tanners and tanning pills is described.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4345932/>)

### *Reading Supports*

The pages that follow include reading supports in the form of an Anticipation Guide, Reading Strategies, 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.

* **Anticipation Guide (page 34):** 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.

**Or** consider the following ideas to engage your students in reading:

**What’s Sunless Tanner?**

* Before reading, ask students why people might use a sunless tanner, and what questions they have about sunless tanners.
* As they read, students should record information they find interesting and look for answers to their questions.
* **Graphic Organizer (page 35):** 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 (pages 36, 37):** 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.

Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.

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. The “Web Resources for More Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

### Anticipation Guide

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

**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. Sunless tanner was discovered by a dermatologist. |
|  |  | * + - 1. Sunless tanner reacts with the skin chemically. |
|  |  | * + - 1. According to the U.S. Centers for Disease Control and Prevention, only UV-B radiation causes skin cancer. |
|  |  | * + - 1. Dihydroxyacetone, found in many sunless tanners, is unstable so additives are used to lower the pH. |
|  |  | * + - 1. Dihydroxyacetone is often produced from glycerol in an enzymatic process. |
|  |  | * + - 1. A new sunless tanner promotes melanin production in people. |
|  |  | * + - 1. Sunless tanning is less safe than sunbathing outdoors. |
|  |  | * + - 1. Sunless-tanning pills contain the same chemical as sunless tanners that are applied to the skin. |
|  |  | * + - 1. Mineral sunblocks contain nanoparticles. |
|  |  | * + - 1. The effects of sunless-tanning products on people has been well-studied. |

### Graphic Organizer

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

**Directions**: As you read the article, complete the graphic organizer below to describe dihydroxyacetone.

**Summary:** On the back of this paper, write a short email (a few sentences) to a friend who wants to use sunless tanner, summarizing what you learned in the article.

|  |  |
| --- | --- |
|  | **Dihydroxyacetone** |
| **How was it discovered?** |  |
| **How does it work to produce a tan?** |  |
| **What are some problems in manufacturing it?** |  |
| **Is it safe to use? What studies have been done?** |  |
| **What are some alternatives to dihydroxyacetone? How do they work?** | |

### Student Reading Comprehension Questions

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

Name

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

* 1. (a) What did Dr. Wittgenstein discover? (b) What was she studying?
  2. In addition to bronzing skin rapidly, list three characteristics of dihydroxyacetone.
  3. Draw (a) the molecular formula for dihydroxyacetone, and (b) its structural formula.

a. Molecular formula b. Structural formula

* 1. (a) What was accidentally discovered in vomit, and (b) how was it discovered?
  2. How did Dr. Wittgenstein prove that dihydroxyacetone reacts with skin?
  3. What is the Maillard reaction?

**Student Reading Comprehension Questions, cont.**

* 1. What was the myth, and what is the truth, about UV exposure?
  2. (a) Why do cosmetic companies need to change the formulation of dihydroxyacetone, and (b) how do they do this?
  3. How can pure dihydroxyacetone be produced?
  4. (a) How does Bronzyl work, (b) what is its active ingredient, and (c) how can it offer safety advantages?
  5. Why is it difficult to study the effects of sunless tanner on healthy skin cells?

Critical-Thinking Question

***Write your answer on another piece of paper, if needed.***

Why do cooks prefer to brown a roast before putting it into the stew pot?

### Answers to Reading Comprehension Questions

1. **What did Dr. Wittgenstein discover, and (b) what was she studying?**

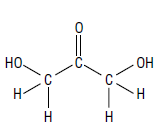
Dr. Wittgenstein discovered a chemical that could bronze skin rapidly.

She was studying children who had a rare metabolic disease and examining the effects of treating them with dihydroxyacetone.

1. **In addition to bronzing skin rapidly, list three characteristics of dihydroxyacetone.**

In addition to bronzing skin rapidly, three characteristics of dihydroxyacetone are that it is

1. a plant-derived,
2. sugar-like molecule,
3. shaped like the letter “m”.
4. **Draw (a) the molecular formula for dihydroxyacetone, and (b) its structural formula.**



a. Molecular formula b. Structural formula

C3H6O3

1. **What was accidentally discovered in vomit, and (b) how was it discovered?**
2. The browning abilities of dihydroxyacetone were discovered in children’s vomit.
3. When patients spit up dihydroxyacetone on themselves, it left strange brown spots on their skin, but their clothes remained unstained.
4. **How did Dr. Wittgenstein prove that dihydroxyacetone reacts with skin?**

To prove that dihydroxyacetone reacts with skin, Dr. Wittgenstein poured a solution of dihydroxyacetone on her own skin and it turned her skin brown, too.

1. **What is the Maillard reaction?**

In the Maillard reaction, sugars and amino acids react when heated to form many molecules, including some that are brownish.

1. **What was the myth; what is the truth about UV exposure?**

*Safe* UV exposure was a myth; the truth is that melanomas are caused by both types of UVradiation.

1. **Why do cosmetic companies need to change the formulation of dihydroxyacetone, and (b) how do they do this?**
   1. Cosmetic companies need to change the formulation of dihydroxyacetone because the molecule is unstable and could cause the skin to be yellow colored.
   2. Cosmetic companies now use different solvents and additives to lower the pH and stabilize dihydroxyacetone.
2. **How can pure dihydroxyacetone be produced?**

Pure dihydroxyacetone can be produced using an enzymatic process with glycerol as the starting material.

1. **How does Bronzyl work, (b) what is its active ingredient, and (c) how can it offer safety advantages?**
2. Bronzyl works by enhancing a person’s melanin production.
3. Bronzyl’s active ingredient is dihydroxymethylchromonyl palmitate.
4. Bronzyl’s safety advantage is that it promotes the production of melanin, which dissipates UV light.
5. **Why is it difficult to study the effects of sunless tanner on healthy skin cells?**

It is difficult to study the effects of dihydroxyacetone on healthy cells due to the problems involved in estimating exposure levels, such as the amount of sunless tanner applied and how long it stays active on the skin.

**Critical-Thinking Question**

**Why do cooks prefer to brown a roast before putting it into the stew pot?**

Browning the roast causes a reaction between the amino acids (in proteins) and the carbohydrates (reducing sugars) in meat to combine in the Maillard reaction, producing browning—plus delicious flavors, color, and aroma. If the meat is put directly into the boiling water in the stew pot, the temperature can only reach approximately the temperature of boiling water (100 oC), a temperature too low to initiate the Maillard reactions that occur at approximately 140 to 165 °C.



**Teacher's Guide for**

### *“The Periodic Table Turns 150: Is the Best Yet to Come?”*

**February/March 2019**

**Table of Contents**

[Tools and Resources 41](#_Toc523845424)

[Connections to Chemistry Concepts 41](#_Toc523845425)

[Possible Student Misconceptions 42](#_Toc523845427)

[Anticipating Student Questions 44](#_Toc523845428)

[Activities 46](#_Toc523845429)

[References 48](#_Toc523845430)

[Web Resources for More Information 49](#_Toc523845431)

[*Reading Supports* *51*](#_Toc523845432)

[Anticipation Guide 53](#_Toc523845433)

[Graphic Organizer 54](#_Toc523845434)

[Student Reading Comprehension Questions 55](#_Toc523845435)

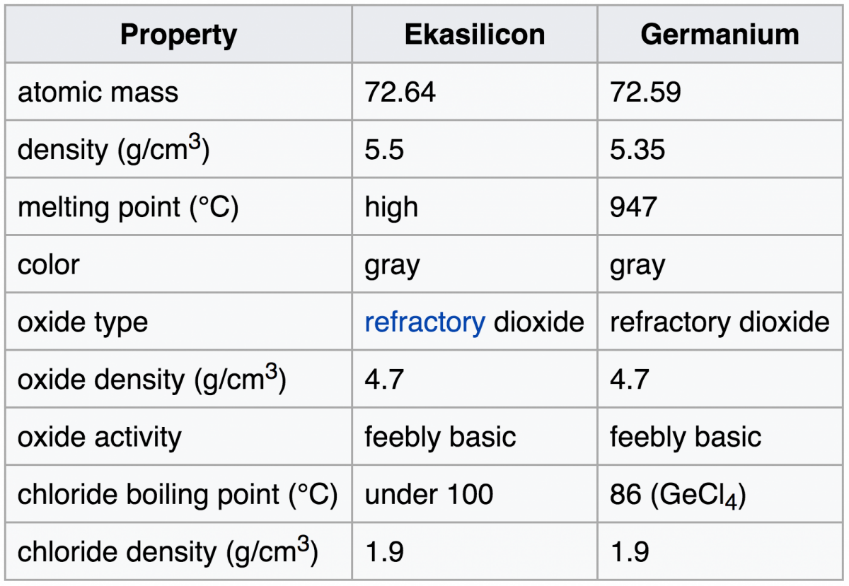
[Answers to Reading Comprehension Questions 57](#_Toc523845436)

### *Tools and Resources*

### Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **History of the periodic table** | The article provides students with the historical context for the look and function of the current periodic table. |
| **Periodic law** | The concept of periodicity, and the roles of protons in differentiating the elements and of electrons in determining elemental properties, may help students understand why individual elements are different and how the properties of these different elements seem to repeat. |
| **Electron orbitals** | The role of electrons in the organization of the periodic table allows the teacher to reinforce the importance of electrons in the properties of the elements. |
| **Chemical properties** | The article explains how scientists often used chemical properties of the elements and their compounds to understand and develop organizational patterns which led to the periodic table. |
| **Protons** | The importance of Rutherford’s work with the proton number and Henry Moseley’s work with x-ray spectroscopy described in the article provides justification for arranging elements in the periodic table by increasing positive nuclear charges (protons), rather than by increasing mass as was done in Mendeleev’s original table. |
| **Superactinides** | The predicted existence of these elements by Seaborg and the islands of stability due to completed nuclear rings helps the teacher to explain scientific opportunities for the discovery of future elements and their placement in the periodic table. |

### Possible Student Misconceptions

1. **“The periodic table is constructed in order of increasing mass.”** Dmitri Mendeleev’s original 1869 periodic table was designed on increasing atomic mass. This was a logical way to sequence the known elements. However, there were sequencing problems with the chemical and physical properties of a few elements (e.g., Co and Ni) when arranged by increasing mass: they appeared out of place according to their properties. In some cases, there wasn’t a known element that would logically fill into a specific space. Mendeleev did not have an explanation for the incorrect properties when sequenced by increasing mass, and the reason for the incorrect sequencing was not totally understood until the proton was discovered by Rutherford in 1920. For most elements, as the number of protons, or atomic number, increased, their atomic masses increased correspondingly. In 1913, Moseley’s experiment with x-ray spectroscopy allowed him to count the number of positive charges in the nucleus of many elements. This information allowed him to explain why cobalt and nickel (as well as some other elements) were seemingly out of place in Mendeleev’s periodic table based on increasing mass. Moseley’s work identified cobalt with a mass of 58.93 amus contained 27 positive nuclear charges, while the lighter nickel with a mass of 58.69 amus had 28 positive nuclear charges. Based on this work, Moseley revised the periodic table to sequence the elements in order of increasing positive nuclear charge, which corrected problems with Mendeleev’s table. Increasing atomic number (protons) is the basis for the current periodic table.
2. **“The first 92 elements all occur naturally and are not radioactive.”** Some people may believe that the first 92 elements (hydrogen through uranium) are naturally occurring and not radioactive, but this is not entirely true. Most people certainly know about atomic bombs and nuclear power plants that rely upon uranium’s (element 92) radioactivity. While the common forms of elements 1–83 are not radioactive, all elements with atomic numbers greater than 83 (bismuth) are radioactive, and most elements with atomic numbers 1–83 have at least one radioactive isotopic form. For example, carbon (which exists as graphite, charcoal, diamond, and buckminsterfullerene) is not radioactive as the common carbon-12 isotope but is radioactive in its carbon-14 form. The discovery of technetium (element 43) was not confirmed until 1937, and it was the first man-made element. Since its discovery, extremely small quantities of technetium have been located in the Earth, but the quantities are so minute that it is synthesized rather than mined. So, technically, all of the elements   
   1–92 occur naturally in some quantity in the Earth, but most are radioactive in at least one isotopic form.
3. **“Dmitri Mendeleev invented the current periodic table.”** Dmitri Mendeleev is usually credited with designing the original periodic table we use today in a modified form, but many people have been involved with classifying and organizing the known elements. Mendeleev’s original 1869 periodic table has been modified by Mendeleev himself in 1871, Moseley in 1913, and Seaborg in 1944 to arrive at the common periodic table that is used today.
4. **“So, now that row seven of the periodic table is complete, there are no new elements to be discovered or places to put them in the periodic table.”** While that might seem logical, it is not correct. The completion of row seven in the periodic table does provide symmetry and a sense of completion, but the article states that more elements may be out there awaiting discovery, and Seaborg suggested the possibility of a superactinide series of elements that may increase the number of elements on the periodic table to 157. The placement of these new elements in the table would likely follow their outer electron configuration arrangements just as the previous elements have done.
5. **“Mendeleev must have known there was some other as-of-yet undiscovered particle (i.e., the proton) when he arranged elements like cobalt and nickel on his table, seemingly in the wrong order based on their atomic masses.”** Not really. He only knew that the physical and chemical properties dictated his placing them where he did.
6. **“The number of neutrons in the nucleus doesn’t have much influence on an element’s properties, because the number of protons determines the specific element and the number and arrangement of outer electrons determine the reactivity.”** Actually, the number of neutrons in the nucleus of an atom has an important influence on the element and its properties. The stability of an element is partly a function of the ratio between protons and neutrons in the nucleus of the atom. If that ratio is too far out of balance, the nucleus becomes unstable and radioactive, in an attempt to achieve greater stability. So, neutrons influence whether an isotope of an element will be radioactive. Also, the article explains that the number of neutrons in the nuclear ring plays a role in the half-life of an isotope of the super-heavy elements and may allow some of these elements to last longer than mere seconds.
7. **“I heard that Mendeleev accurately predicted the missing elements and their properties when he organized his original 1869 periodic table.”** It’s true that in 1869, when he was placing the 63 then-known elements into his periodic table, Mendeleev left spaces for undiscovered elements and made predictions about their properties. However, the accuracy of his predictions varied. Mendeleev’s most successful predictions involved the element he called eka-silicon (meaning one down from silicon), which we now know as germanium. He also had relatively accurate predictions for eka-boron (now scandium), eka-aluminum (now gallium), and eka-manganese (now technetium). Other predictions (some later than 1869) such as for protactinium (then eka-tantalum) were wrong in location. Mendeleev also predicted a heavier element similar to titanium and zirconium, but he incorrectly placed lanthanum below them. Amazingly, Mendeleev was often correct in his predictions, but not perfect.

*(*[*https://en.wikipedia.org/wiki/Mendeleev%27s\_predicted\_elements*](https://en.wikipedia.org/wiki/Mendeleev%27s_predicted_elements)*)*

### Anticipating Student Questions

1. **“Are there additional forms of the periodic table, besides the one in my textbook or the poster on the wall?”** Yes! There are possibly hundreds of different forms of the periodic table of the elements, each with a unique way of showing the periodic nature and properties of the elements. The traditional, or condensed, form of the periodic table shows elements 1–118 in a castle-like shape with two long rows underneath the main structure. Other forms include a galaxy shape, a pyramid, a circle, a spiral, 3-dimensional, and many others. (<https://www.meta-synthesis.com/webbook/35_pt/pt_database.php>)
2. **“Why are there two rows of elements (lanthanides and actinides) separated at the bottom of the periodic table?”** The most common form of the periodic table separates the lanthanide and actinide elements from the main body of the table. There are two reasons offered for this separation. First, by placing the lanthanide and actinide elements separately below the main table, the physical size of the table is reduced in length. This allows the table to be printed on standard 8.5” x 11” printer paper in a size that can easily be read by most people. It also avoids having to have a troublesome fold-out page in a textbook or the extreme cost associated with producing a very long wall chart. The second reason is that chemically the lanthanide and actinide elements have some similar properties due to their   
   f-block electrons buried deeply within the atoms. Because of their similar properties, the lanthanide and actinide elements were originally difficult to separate and identify as individual elements.
3. **“How are new elements discovered and verified?”** Each element has a unique number of protons—its atomic number. So, simplistically, all that is required to form a new element is to add another proton to the nucleus of the previous largest element. In a sense, it would be like finding the largest number—all one has to do is take the previous number and add one more to it. This process worked for elements 95–100. But, in reality, it is not that easy because all elements past number 83 are radioactive, and some exist only for seconds before decaying into a different element. So adding another proton, isolating, and identifying the new element prior to its decay is exceedingly difficult. In practice, scientists fire smaller elements (hydrogen through zinc) at larger, relatively stable nuclei to form super-heavy elements. However, the difficulty is that, as the smaller element projectiles get larger in mass, it takes greater energy to smash them into the target atoms. This energy, the time, and the cost are current limits to producing new elements—but the search won’t stop. Once synthesized by one laboratory, another laboratory must halt its work on synthesizing a new element to duplicate and verify the results of the reported discovery. Currently, there are only a few facilities in the world conducting research on the synthesis and verification of new elements, including the Riken Institute in Japan, the Joint Institute for Nuclear Research in Russia, the Lawrence Livermore National Laboratory in California, the Oak Ridge National Laboratory in Tennessee, and GSI in Germany.
4. **“Are there any practical uses for the transuranium elements?”** There are a number of uses for several of the transuranium elements. Plutonium (element 94) is used as a fuel in fast-breeder reactors, in nuclear weapons, and as a compact energy source for spacecraft, etc. Americium (element 95) is an alpha-particle emitter for smoke alarms. Both americium and californium (element 98) have isotopes used in medicine (cancer treatments) and in industry (well logging). The costs of producing these transuranic elements (from $4,000/gram for plutonium to $60,000,000/gram for californium) limits their potential uses. Elements past californium have essentially no industrial applications due to costs, limited supply, and very short lives.
5. **“Do any elements exist between the ones currently on the periodic table?”** If you mean, “Is there a possible element between, for example, iron (element 26) and cobalt (element 27)?”—the answer is no. Because elements are arranged in the periodic table by increasing atomic number (protons), there is not an element with a fractional number of protons like an atomic number of 26.5 that could occur between iron and cobalt. However, there have been times when there were gaps in the periodic table where the missing element contained a whole number of protons but hadn’t been isolated yet. An example from several years ago was when current element 117 (tennessine) was undiscovered, while numbers 116 and 118 had been synthesized, leaving a gap between them, until 2010 when tennessine was announced.
6. **“Why do elements in columns or families in the periodic table have similar properties?”** The properties of individual elements are largely determined by their electron configurations—especially the number and arrangement of their outer-energy-level electrons. Because of the periodic table’s arrangement into columns with similar outer electron configurations—and those outer electron configurations influencing properties—the elements in each column will have similar (but not identical) properties.
7. **“Why do some periodic tables (like the one hanging in my classroom?) have strange letters like Uut, Uup, Uus, and Uuo for some of the newer elements?”** That’s a great question! Once a new element has been announced and verified by a research group, it is assigned a placeholder name until the International Union of Pure and Applied Chemistry (IUPAC) determines who has the honor of naming the new element and officially accepting the name that is proposed. This process can take many years. In the meanwhile, the new element is assigned a working name and symbol composed of the Latin names for the digits in its atomic number. So, Uut was ununtrium, spelling out the numbers 1, 1, and 3 for element 113; likewise, Uup was ununpentium, for 115; Uus was the symbol for ununseptium, spelling out 117; and Uuo was the symbol for ununoctium, number 118.

### Activities

**Labs and demos**

**“Electron Configuration and the Periodic Table” lab:** Students write electron configurations for selected elements, predict electron configurations for other atoms, and predict reactivity based upon an atom’s electron configuration and position in the periodic table. (Access is restricted to AACT members, but the article will be available for free until April 1, 2019, at <https://teachchemistry.org/classroom-resources/electron-configuration-and-the-periodic-table>.)

**“Periodic Pasta Table” lab:** Students use a cardboard base and spaghetti noodles to create a three-dimensional model of a periodic property for the periodic table. The lab activity includes photographs, student and teacher hints, extensions, and directions. (<https://www.exploratorium.edu/snacks/periodic-pasta-table>)

**Simulations**

“**Alien Periodic Table”:** This activity simulates the organization of the periodic table into groups and periods, allowing students to find patterns and visualize the Periodic Law using cartoon drawings of “aliens”. (<https://www.gulfcoast.edu/current-students/academic-divisions/natural-sciences/biology-project/chemistry-1/documents/alien-periodic-table.pdf>)

**Media**

**“The Periodic Table – Classification of Elements” (8:55):** This Khan Academy video names the chemical families, defines groups and periods, and explains how metals, metalloids, and non-metals can be identified by their locations in the table; it also discusses the elements’ reactivities. (<https://www.youtube.com/watch?v=t_f8bB1kf6M>)

**“Periodic Videos”, (times vary):** Select an element and this interactive periodic table links to a video (of varying length) about each element numbers 1–118 providing information including visuals, history, uses, and interesting facts. (<http://periodicvideos.com/>)

**Lessons and lesson plans**

**“The Periodic Table Unit Plan” lesson unit:** this guide provides 7-10 days of resources and a dozen activities for supporting students’ learning of the periodic table, properties, and trends with links to all resources. (Access is restricted to AACT members, but the article will be available for free until April 1, 2019, at <https://teachchemistry.org/classroom-resources/the-periodic-table-unit-plan>.)

**“The Periodic Table of the Elements” lesson:** This site provides a lesson overview with links to activities including multimedia and print materials, looking at the origin of the periodic table and the anatomy of the periodic table. (<https://www.pbslearningmedia.org/resource/phy03.sci.phys.matter.lp_pertable/the-periodic-table-of-the-elements/>)

**Projects and extension activities**

**“Group and Periodic Properties Lab” extension lab:** Students perform experiments with sodium, potassium, calcium, magnesium, sulfur, and phosphorous to observe reactions and form conclusions about trends down groups and across periods. The teacher will need to determine if these activities can be safely performed by students, due to the limited instructions and teacher supports, or if they should be used only as teacher demonstrations, due to safety and laboratory equipment issues; some can be done either way. (<https://serc.carleton.edu/sp/mnstep/activities/26404.html>)

**“A Research Paper on the Elements, in 3-D” project:** Students research an element, construct a paper icosahedron, and display information about the element on the faces of their icosahedron. Although the abstract states the audience for this project is elementary and middle school students, it is also successful with high school students. (<https://pubs.acs.org/doi/pdf/10.1021/ed086p1142>. 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.)

### References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles and Teacher’s Guides published from the first issue in October 1983 through April 2013.**

**The DVD is available from the ACS for $42 ($135 for a site/ school license) here:** [***http://www.acs.org/chemmatters***](http://www.acs.org/chemmatters)***.***



“The New Alchemy” describes the stars as the source of all elements on Earth, the formation of new elements through transmutation, and the revision of the periodic table through the work of Seaborg and McMillan. (McClure, M. The New Alchemy. *ChemMatters*. 2006, *24* (3), pp 15–17)

In “What Uuought to Know about Elements 112–118”, readers will learn about the process of making and discovering super-heavy elements using projectiles and element targets. (Brownlee, C. What Uuought to Know About Elements 112–118. *ChemMatters*. 2008, *26* (3), pp 9–10)

“The Many Looks of the Periodic Table” displays and discusses the traditional format of the periodic table, along with variations that include a spiral, a galaxy, a circle, and a three-dimensional table. (Katz, G. The Many Looks of the Periodic Table. *ChemMatters*. 2008, *26* (3), pp 12–14)

“Where Do Chemical Elements Come From?” describes the nucleosynthesis of the elements in the stars, starting with hydrogen and the formation of helium through iron in younger stars, to the formation of heavier elements in supernovas. (Ruth, C. Where Do Chemical Elements Come From? *ChemMatters*. 2009, *27* (3), pp 6–8)

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

The majority of the September 8, 2003 issue of *Chemical and Engineering News* was devoted to the celebration of the magazine's 80th anniversary, by looking at the periodic table. Color graphics and 89 varied essays provide perspective on the periodic table and the elements. (Chem. Eng. News, 2003, *81* (36)

This 2018 article describes how the authors arranged students into a representation of the “s” and “p” elements of the periodic table, with each student portraying a specific element. The instructor directed students to evaluate statements of peers and analyze periodic trends, while answering questions to learn about the periodic table’s predictive powers. (Hoffman, A.; Hennessy, M. The People Periodic Table: A Framework for Engaging Introductory Chemistry Students. *J. Chem. Educ.*, 2018, *95* (2), p 281–285; <https://pubs.acs.org/doi/10.1021/acs.jchemed.7b00226>. 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 Resources for More Information

**History of the periodic table**

This site explains the development of the periodic table from Aristotle through Seaborg.

(<http://www.newworldencyclopedia.org/entry/History_of_the_periodic_table>)

This Wikipedia site is a timeline for information on the discovery of each element.

(<https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries>)

**Dmitri Mendeleev’s and Julius Lothar Meyer’s similar periodic tables**

This resource provides biographical material and information on Mendeleev’s work to develop the periodic table.

(<https://www.khanacademy.org/partner-content/big-history-project/stars-and-elements/knowing-stars-elements/a/dmitri-mendeleev>)

Meyer developed a periodic table similar to Mendeleev, and this site looks at the work of both Meyer and Mendeleev and the contributions of each man.

(<https://www.sciencehistory.org/historical-profile/julius-lothar-meyer-and-dmitri-ivanovich-mendeleev>)

**Johann Döbereiner’s and John Newlands’ early classification attempts**

John Newland’s work on the Law of Octaves for organizing the elements is explained at this site, along with diagrams to help readers.

(<https://www.wonderwikikids.com/conceptmaps/Newlands_Law.html>)

This site is a brief biography for Döbereiner and his work in chemistry, including his organization of elements into triads.

(<http://www.eoht.info/page/Johann+Dobereiner>)

**Henry Moseley’s and Glenn Seaborg’s contributions to the modern periodic table**

Moseley’s contributions to improving the periodic table by ordering elements in increasing atomic number are explained in this biography, along with his other scientific contributions.

(<http://www.chemistryexplained.com/knowledge/Henry_Moseley.html>)

Glenn Seaborg’s life and contributions to science, including his discovery of elements and his major revision to the periodic table, are described in this reference.

(<https://www.famousscientists.org/glenn-seaborg/>)

**Periodic tables**

“The Internet Database of Periodic Tables” is a vast and comprehensive source of all things related to periodic tables.

(<https://www.meta-synthesis.com/webbook/35_pt/pt_database.php>)

**Electron energy levels and the periodic table**

This is a clear description of how electrons are organized in atoms and how this organization is the basis for the periodic table.

(<https://www.khanacademy.org/science/biology/chemistry--of-life/electron-shells-and-orbitals/a/the-periodic-table-electron-shells-and-orbitals-article>)

**Periodic properties and trends**

The periodic properties of elements, including atomic radius, ionization energy, electron affinity, electronegativity, metallic character, and others, are explained and illustrated in this resource.

(<https://chem.libretexts.org/Textbook_Maps/Inorganic_Chemistry/Supplemental_Modules_(Inorganic_Chemistry)/Descriptive_Chemistry/Periodic_Trends_of_Elemental_Properties/Periodic_Properties_of_the_Elements>)

**Nuclear structure, shells, and the island of stability**

This technical article provides in-depth information on the nucleus, the nuclear shell model, and super-heavy elements.

(<https://www.nap.edu/read/6288/chapter/5#61>)

Neil DeGrasse Tyson narrates this NOVA video (13:10) explaining the island of stability.

(<https://www.youtube.com/watch?v=pkV63_Y6Klw>)

**Interactive periodic table**

Click on any element in this interactive periodic table to explore facts, uses, properties, history, atomic data, oxidation states, and isotopes. In addition, podcasts, videos, resources, references, and more are available for most of the elements.

(<http://www.rsc.org/periodic-table>)

**Discovering new elements**

This site emphasizes that many more elements remain to be discovered and discusses the research process and the rivalry among research teams; the site includes colorful graphics.

(<http://www.bbc.com/earth/story/20160115-how-many-more-chemical-elements-are-there-for-us-to-find>)

**Even more resources**

The ACS ChemClub site provides over a dozen Web sites, puzzles, videos, and other activities for possible projects or lesson extensions. (<https://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/periodic-table.html>)

A search of the “Compound Interest” Web site for “element infographics” brings up infographics of groups 1–8, plus the transition elements, lanthanides, actinides, and transactinides.

(<https://www.compoundchem.com/>)

### *Reading Supports*

The pages that follow include reading supports in the form of an Anticipation Guide, Reading Strategies, 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.

* **Anticipation Guide (page 53):** 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.

**Or** consider the following ideas to engage your students in reading:

**The Periodic Table Turns 150: Is the Best Yet to Come?**

* Before reading, ask students why the Periodic Table is organized the way it is.
* As they read, students can find information to confirm or refute their original ideas.
* **Graphic Organizer (page 54):** 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 (pages 55, 56):** 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.

Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.

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. The “Web Resources for More Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

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. Mendeleev was the first person to categorize elements based on their physical and chemical characteristics. |
|  |  | 1. At the time when Mendeleev published his periodic table, there were 92 known elements. |
|  |  | 1. Mendeleev knew about protons. |
|  |  | 1. Mendeleev predicted the existence of elements that had not yet been discovered, along with their properties. |
|  |  | 1. Organizing the periodic table according to atomic number validated Mendeleev’s approach. |
|  |  | 1. Hydrogen is found at the top of Group 1 because it is a metal. |
|  |  | 1. Mendeleev put the lanthanides and actinides below the main part of the periodic table. |
|  |  | 1. Period 7 in the periodic table is complete. |
|  |  | 1. The periodic table keeps changing. |
|  |  | 1. Nobel laureate Glenn Seaborg hypothesized the existence of a superactinide series of stable elements. |

### Graphic Organizer

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

**Directions**: As you read the article, complete the graphic organizer below to summarize what you learned about the periodic table from your reading.

|  |  |  |
| --- | --- | --- |
| 3 | **New things you learned about the periodic table** |  |
| 2 | **Ideas from the article that will help you in chemistry class** |  |
| 1 | **Question you have about the periodic table** |  |
| Contact! | **How do you think the periodic table might change in your lifetime, and why do you think so?** |  |

### Student Reading Comprehension Questions

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

Name

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

* 1. What was Dmitri Mendeleev’s dream that reportedly was the start of his periodic table?
  2. What is periodicity?
  3. How did (a) Antoine Lavoisier, (b) Johann Döbereiner, and (c) John Newlands attempt to organize the elements?
  4. (a) What is a hydride, and (b) how did Mendeleev use hydrides in developing his table?
  5. (a) What was Mendeleev’s most insightful decision in organizing his early periodic table, and (b) why?
  6. What revision to Mendeleev’s original periodic table did he make in 1871?

**Student Reading Comprehension Questions, cont.**

* 1. How did Henry Moseley change the periodic table in 1913 to its modern form?
  2. Why is the placement of hydrogen on the periodic table a debate for some scientists?
  3. Although the elements in the lanthanide and actinide series sit below the main table, where do they really belong?
  4. Explain (a) Seaborg’s “island of stability” concept, and (b) how it involves the nucleus of the atom.

**Critical-Thinking Questions**

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

1. Compare electron energy levels and nuclear rings, both physically and chemically.
2. Use the Internet to research other periodic table arrangements and select one; then explain why you chose it and discuss its advantages and disadvantages over the commonly-used table.

### Answers to Reading Comprehension Questions

1. **What was Dmitri Mendeleev’s dream that reportedly was the start of his periodic table?**

Dmitri Mendeleev was reported to have had a dream where the chemical elements lined up in their order of increasing atomic mass, and a pattern emerged.

1. **What is periodicity?**

Periodicity is a repetition of behavior (in this case, chemical properties) at regular intervals.

1. **How did (a) Antoine Lavoisier, (b) Johann Döbereiner, and (c) John Newlands attempt to organize the elements?**

a. Lavoisier categorized the elements into metals, non-metals, earths, and gases based on their characteristics.

b. Döbereiner noticed some patterns among triplets of elements.

c. Newlands noticed chemical periodicity and compared the phenomenon to musical octaves where repeats occurred in groups of eight.

1. **(a) What is a hydride, and (b) how did Mendeleev use hydrides in developing his table?**

a. A hydride is a compound of hydrogen with another element.

b. Mendeleev studied the chemical formulas of different hydrides and noticed a pattern that helped him develop his table.

1. **(a) What was Mendeleev’s most insightful decision in organizing his early periodic table, and (b) why was it so important?**
2. Mendeleev’s insightful decision in organizing his periodic table was to let properties trump atomic weight when placing the elements.
3. This process allowed Mendeleev to skip slots in his table where the elements’ properties did not match known elements and to predict undiscovered elements.
4. **What revision to Mendeleev’s original periodic table did he make in 1871?**

In 1871, Mendeleev reversed his original arrangement so that the new table lined up elements with similar properties vertically, and periods were in horizontal rows so that the table looks similar the one today.

1. **How did Henry Moseley change the periodic table in 1913 to its modern form?**

In 1913, Henry Moseley developed the first modern periodic table by basing the element sequence on atomic number (number of protons) rather than on atomic mass.

1. **Why is the placement of hydrogen on the periodic table a debate for some scientists?**

Hydrogen’s placement is debatable because, in some ways, its chemical behavior is like group 17 (7A) elements, yet in other ways, it is like group 1 elements.

1. **Although the lanthanide and actinide series elements sit below the main table, where do they really belong?**

The lanthanide and actinide series elements really belong in the periodic table in periods 6 and 7, respectively, and between groups 2 and 3.

1. **Explain (a) Seaborg’s “island of stability” concept, and (b) how it involves the nucleus.**

a. Seaborg’s island of stability concept is when super-heavy elements become more stable and, therefore, have longer lives.

b. In the island of stability idea, the nucleus has rings composed of a particular number of protons and neutrons and that when full, the super-heavy element with filled nuclear rings would become stable for longer periods of time.

**Critical-Thinking Questions**

1. **Compare electron energy levels and nuclear rings, both physically and chemically**

Both electron energy levels and nuclear rings are ways to organize subatomic particles. For electron energy levels, the electrons fill in until the energy level is full, which produces chemical stability. For the nuclear rings, protons and neutrons are physically filled in until the ring is full, which produces nuclear stability.

1. **Use the Internet to research other periodic table arrangements and select one; then explain why you chose it and discuss its advantages and disadvantages over the commonly-used table.**

Student answers will vary depending upon which periodic table they select for comparison. Possible advantages might include that the selected table

1. is easier to comprehend,
2. has better continuity,
3. provides a better visualization of electron arrangements, and
4. includes the lanthanide and actinide elements into the main table.

Possible disadvantages might include that the selected table

1. has smaller print and is, therefore, harder to read because it includes the lanthanide and actinide elements in the main table,
2. is larger and more unwieldy because it includes the lanthanide and actinide elements in the main table,
3. has a less traditional format and is therefore unfamiliar and harder to understand, and
4. is less clear in showing relationships among periods or groups.



**Teacher's Guide for**

### *“Clean & Green”*

**February/March 2019**

**Table of Contents**

[Tools and Resources 60](#_Toc523845734)

[Connections to Chemistry Concepts 60](#_Toc523845735)

[Possible Student Misconceptions 61](#_Toc523845737)

[Anticipating Student Questions 62](#_Toc523845738)

[Activities 63](#_Toc523845739)

[References 65](#_Toc523845740)

[Web Resources for More Information 66](#_Toc523845741)

[*Reading Supports* *68*](#_Toc523845742)

[Anticipation Guide 70](#_Toc523845743)

[Graphic Organizer 71](#_Toc523845744)

[Student Reading Comprehension Questions 72](#_Toc523845745)

[Answers to Reading Comprehension Questions 74](#_Toc523845746)

### *Tools and Resources*

### Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Scientific processes** | Preparation for chemistry lab work provides an excellent place in the curriculum for students to compare the differences between the processes of standard procedures and green laboratory procedures, as shown in this article. |
| **Sublimation** | While studying phase changes, the extraction of essential oils discussed in this article provides a great example of a real-world application of sublimation. |
| **Phase changes** | As described in the article, the odors emitted by essential oils can be attributed to the important nature of their volatile molecules that easily undergo the liquid/gas phase change. |
| **Greenhouse gases** | While studying how greenhouse gases affect our atmosphere and climate, this article provides information through an industrial example of ways to reduce the presence of carbon dioxide in the atmosphere. |
| **Carbon footprint** | Information from this article can be used to show the importance of considering energy use when calculating the carbon footprint of a laboratory procedure. |
| **Triple point** | When phase changes and triple points are studied, industrial use of these chemical concepts, as described in this article, can enhance student interest. |
| **Separation techniques** | The extraction of essential oils mentioned in this article is an example of a separation process—one which can be done either by steam distillation or the use of supercritical carbon dioxide. |

### Possible Student Misconceptions

1. **“To make our world greener, I understand how important it is to ban the use of all the chemicals that are hazardous to the environment and to humans.”** It will not be practical to stop using all hazardous chemicals, as some are essential ingredients for reactions to make medicines and other necessary products. However, whenever possible, hazardous chemicals should be replaced by alternatives that have been proven safe.
2. **“Industry should use only biodegradable chemicals.”** Actually, it is important to avoid using chemicals that stay as waste in the environment or bio-accumulate. However, many chemicals that are not biodegradable can be considered valuable resources if they can be removed from waste by recycling or reusing.
3. **“We should be using water as a solvent for almost everything.”** While water is an excellent green solvent for polar materials, when used in reactions with nonpolar organic compounds it may affect the reactivity of the reactants and the catalysts. Moreover, if some of the organic material dissolves in the water, it may be very difficult to remove by water treatment processes. So while water is a good solvent, it should not be taken for granted that it is the best solvent for all situations.
4. **“When staying in a hotel, I tell my family to always follow the instructions on the card with large GREEN letters asking us to join the effort to save the environment by using the ‘green’ choice to ‘opt out’ of washing sheets and towels.”** This claim is misleading in terms of green chemistry because probably little or nothing has been done by the hotel to “green” the process of cleaning the laundry. This practice often called ‘greenwashing’ doesn’t save the environment; it just saves money for the hotel because they wash linens less frequently.
5. **“As a priority, we really need to look at producing less waste from chemical reactions.”** Yes, this is important but, actually, it would be wiser to carefully consider the contents of the waste. Perhaps some of the waste products can be recycled or used again. This will prevent them from polluting the environment as well as further reducing the waste.
6. **“Wow, I really found the *chemistry* involved in producing essential oils exciting!”** In the lab, removing essential oils from citrus zest is a *physical*, not a *chemical* change. The oil in the zest was not chemically produced; it was just separated from the zest. The liquid supercritical CO2 penetrated the zest and merely dissolved the essential oil to physically remove it from the zest.

### Anticipating Student Questions

1. **“Why is green chemistry important?”** Green chemistry practices are important because they promote a healthier, safer, and cleaner environment by creating alternatives to hazardous substances. This is done through the design of chemical processes that reduce waste, use less energy, and reduce the use of limited resources.
2. **“Why does Kiersi need to wear gloves when she holds the test tube of dry ice?”** Kiersi must wear gloves to protect her hands from the very cold dry ice. Carbon dioxide freezes at –78.5 oC (water freezes at 0 oC). So, dry ice is very dangerous to your bare skin; it can burn, freeze, and cause your skin cells to die.
3. **“What does it mean when you refer to a product’s ‘carbon footprint’?”** A product’s carbon footprint is a calculation that represents the total amount of greenhouse gases (which include carbon dioxide) released during the production of a substance. The footprint is calculated as carbon dioxide equivalents and expressed in tons of carbon dioxide (CO2 e) released to the environment. Carbon footprints can also refer to an individual or an event. Students can use this EPA site to calculate their carbon footprints based on their current lifestyle: <https://www3.epa.gov/carbon-footprint-calculator/>.
4. **“Why is the oil from an orange peel called essential?”** Essential oils are so named because their aromas represent the “essence” of the fragrance of the plant from which they were extracted. For example, the oil extracted from orange peel smells like an orange.
5. **“Why do some substances sublime?”** When the vapor pressure of the compound is greater than the total pressure of the atmosphere, and the temperature is below the melting point, the substance can change directly from a solid to a gas. This process is called sublimation.
6. **“Besides dry ice, what other substances undergo sublimation?"** Examples include

* If you watch Ice and snow on a cold day when the temperature is below freezing, you can sometimes see “steam” (really condensed water vapor forming a “cloud” of tiny water droplets) rise directly from the solid.  
  [Note that we can’t actually *see* steam, because steam is water in the gas phase—a colorless gas, just like carbon dioxide or carbon monoxide; we can’t see them, either.]
* Naphthalene (mothballs) also undergoes sublimation. Its vapor is poisonous to moths; however, clothes stored with mothballs are not “wetted” by melted mothball liquid (because there *is* no liquid phase).
* Iodine crystals in a closed, clear glass bottle will soon sublime into a purple gas in the bottle, with some crystals remaining, but no liquid present.

### Activities

**Labs and demos**

**“Reactions Lab”:** In this Beyond Benign chemistry lab, students identify the type of chemical reaction and then choose between two procedures, one traditional and the other a green chemistry alternative. Finally, students will analyze their experiments against the 12 principles of green chemistry. [Note: The URL for the lab described in the Lim green chemistry article is given in the “Lessons” section below.] (<https://www.beyondbenign.org/lessons/reactions-lab/>)

**“Wet Dry Ice Lab”:** Students actually see the triple point of dry ice! This Flinn Fax lab includes a description of the relevant phase diagram. (<https://www.flinnsci.com/api/library/Download/cc3f4560edb447c693d6ad631f971ff3>)

**Media**

**“Extraction of D-Limonene/Dry Ice”, video (4:20):** This video demonstrates the extraction described in the Lim article. Beginning with an explanation of the method using the phase diagram for CO2, all steps of the laboratory procedure including safety are shown and explained as the experiment progresses to the final product. (<https://www.youtube.com/watch?v=4OU65Y6KG00>)

**“How to Make Dry Ice with a Fire Extinguisher”, video (1:53):** This silent video clearly shows how to use a carbon dioxide fire extinguisher to make dry ice, collect it in a pillowcase and dump it into a metal bowl. Note the safety precaution: the demonstrator wears gloves throughout the procedure, including (especially) while handling the dry ice; goggles should also be worn. (<https://www.youtube.com/watch?v=WleXk7eu1tU>)

**Lessons and lesson plans**

**“Essential Oil Extraction Using Liquid CO2” lesson plan:** This Beyond Benign lesson plan includes two complete oil extraction experiments: steam and CO2 (as described in the Lim article. Students are asked to compare the two methods and write how they relate to the “Principles of Green Chemistry”. (<https://www.beyondbenign.org/lessons/essential-oil-extraction-using-liquid-co2/>) (Lesson download available at this URL)

**“The safer chemical design game. Gamification of green chemistry and safer chemical design concepts for high school and undergraduate students”:** Students use this free, downloadable green chemistry computer game to design laboratory exercises that are greener and safer than those used traditionally. (<https://www.tandfonline.com/doi/full/10.1080/17518253.2018.1434566>)

**Projects and extension activities**

**“Chemistry Project on Green Chemistry: Bio-Diesel and Bio-Petrol”:** This project includes three activities: the first and second are lab-based—making (1) and testing (2) bio-diesel—while the third involves using market data to analyze the use of bio-diesel. An introduction to green chemistry is followed by a discussion of its principles and their application during the production of bio-diesel. (<https://www.scribd.com/document/47324592/Chemistry-Project-on-Green-Chemistry-Bio-Diesel-and-Bio-Petro>)

**“Green Chemistry in the General Chemistry Laboratory”:** For extension activities or student projects, consider using (and comparing with standard procedures) the Beyond Benign general chemistry experiments that are greened versions of university-level introductory chemistry labs, which use safer, less toxic replacements for most of the original hazardous chemicals. The site provides an excellent resource, especially for the AP Chemistry lab program. (<https://www.beyondbenign.org/bbdocs/curriculum/higher-ed/CS_General_Chemistry.pdf>)

### References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles and Teacher’s Guides published from the first issue in October 1983 through April 2013.**

**The DVD is available from the ACS for $42 ($135 for a site/ school license) here:** [***http://www.acs.org/chemmatters***](http://www.acs.org/chemmatters)***.***



“The Supercritical Clean Machine” describes the chemistry behind the polymer surfactant design and the ability of supercritical carbon dioxide to “green” the dry-cleaning process that won the 2000 ACS Presidential Green Chemistry Challenge Award. (Kirchoff, M. The Supercritical Clean Machine. *ChemMatters*. 2000, *18* (2), pp 14–15)

“The Swoosh Goes Green: Interview with John Frazier, Environmental and Sustainable Chemist at Nike” discusses the ways that Nike has reduced the release of volatile organic compounds (VOCs) and pesticides to the environment. (Brownlee, C. The Swoosh Goes Green: Interview with John Frazier, Environmental and Sustainable Chemist at Nike. *ChemMatters*. 2008, *26* (3), pp 18–19)

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

The ACS “Chemistry in the Community” (ChemCom) textbook integrates green chemistry throughout the curriculum via icons for brief references and study of the principles of green chemistry through a biodiesel lab used as a green alternative to petroleum for a major energy source. (<https://www.acs.org/content/acs/en/education/resources/highschool/chemcom.html>; free review and electronic or print copies can be ordered at this site.)

### Web Resources for More Information

**History of green chemistry**

Green chemistry advances are described for each decade from the 1960s to the present. There is much information here as well as links to more.

(<https://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/history-of-green-chemistry.html>)

This article is separated into three green chemistry sections: Origins, Present, and Future; the future section focuses on the importance of an interdisciplinary approach to product design for the field of toxicology.

(<https://greenchemistry.yale.edu/about/history-green-chemistry>)

**12 principles of green chemistry**

Each principle is described and denoted by an appropriate icon. The authors suggest that the principles can be grouped as either reducing risk or minimizing environmental impact.

(<https://www.sigmaaldrich.com/chemistry/greener-alternatives/green-chemistry.html>)

A reproducible, full-color bookmark listing the 12 principles can be downloaded here: (<https://www.epa.gov/sites/production/files/documents/green-chemistry-bookmark_1.pdf>)

“Green chemistry: deliverance or distraction?” questions green chemistry principles and includes a good section for classroom use: a table with four headings: “Green chemistry principles”, “Useful questions for discussion”, “What can chemistry tell us”, and “What chemistry cannot tell us”.

(<https://link.springer.com/article/10.1007/s10098-016-1118-y>)

**Essential oils**

This history from *The Essential Oils Academy* describes the use of essential oils around the world, from fragrances for Cleopatra and Egyptian Priests to aromatherapy. The site also includes their use on wounds in WWI and how they are currently applied as natural remedies for health conditions.

(<http://essentialoilsacademy.com/history/>)

The URL below takes you to a very comprehensive site that includes the chemistry of essential oils and their components. A description of the types of compounds that compose various essential oils is followed by links to their uses: as alternative medicines (with recipes); safety concerns; manufacturing methods; and a list of those sold in the U.S.

(<https://essentialoils.co.za/components.htm>)

**Classroom applications**

Knowing the science curriculum is already packed, during this NSTA webinar Michael Tinnesand and Barbara Sitzman present ways to integrate, rather than add, green chemistry into lesson plans. During a lab activity, attendees learn to calculate and compare energy use in a traditional lab with that of a greener version. (<https://learningcenter.nsta.org/products/symposia_seminars/ACS/webseminar2.aspx>)

This review of green chemistry pedagogy suggests that the green chemistry field offers the best way to make chemistry relevant to a wide audience, through programs such as the ACS National Chemistry Week outreach. Along with an extensive bibliography, there is a section on pages 4–5 that focuses on placing green chemistry into the high school curriculum.

(<https://www.researchgate.net/publication/313829252_Green_Chemistry_Pedagogy>)

**Climate change**

The United Nations Climate Change Conference produced the *Paris Agreement* where nations pledged to reduce their greenhouse emissions. This BBC article summarizes the key elements of the agreement.

(<https://www.bbc.com/news/science-environment-35073297>)

Considering “green” as vital for meeting climate targets, three industrial partners from the Amsterdam area are studying the feasibility of forming a very large “green” hydrogen cluster. They plan to cluster (arrange) their industries to form a circular, recyclable process, driven by off-shore wind, which uses emissions from steel companies to produce hydrogen and oxygen for producing new products.

(<https://www.portofamsterdam.com/en/press-release/nouryon-tata-steel-and-port-amsterdam-partner-develop-largest-green-hydrogen-cluster>)

**Supercritical carbon dioxide**

This article describes the importance of using supercritical carbon dioxide as a green replacement for flammable and often toxic traditional solvents. A phase diagram is used to explain the formation of supercritical carbon dioxide; it also includes details of CO2’s use for extraction, and the text includes information about chemical reactions.

(<https://www.chemengonline.com/supercritical-co2-a-green-solvent/?printmode=1>)

Here is an extensive bulleted summary of the advantages of oil extraction by supercritical carbon dioxide. While most involve the health and environment advantages of avoiding organic solvents, taste testing shows that the flavor of extractions by carbon dioxide is closer to that of the real material than extraction by distillation or other procedures.

(<http://web.ist.utl.pt/ist11061/fidel/flaves/sec5/sec5431.html>)

**Beyond Benign**

Beyond Benign provides open access to green and sustainable chemistry curriculum. They have developed over 200 lesson plans and units; they also offer teacher training and workshop presentations.

(<https://www.beyondbenign.org/about/>)

Beyond Benign was one of the collaborators in writing a green-chemistry supplement to the ACS Guidelines for Bachelor’s Degrees in ACS-approved chemistry programs. The supplement “Green Chemistry in the Curriculum” is divided into specific examples of how to integrate green chemistry into basic chemistry courses, including general chemistry topics (similar to topics in the AP Chemistry program), and into the other fundamental bachelor’s degree courses.

(<https://www.acs.org/content/dam/acsorg/about/governance/committees/training/acsapproved/degreeprogram/green-chemistry-in-the-curriculum-supplement.pdf>)

### *Reading Supports*

The pages that follow include reading supports in the form of an Anticipation Guide, Reading Strategies, 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.

* **Anticipation Guide (page 70):** 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.

**Or** consider the following ideas to engage your students in reading:

**Clean &Green**

* Before reading, ask students how chemists try to reduce our impact on the environment.
* As they read, students should add to their original list.
* **Graphic Organizer (page 71):** 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 (pages 72, 73):** 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.

Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.

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. The “Web Resources for More Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

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. Dry ice is solid carbon dioxide. |
|  |  | 1. Most professional chemists receive training in toxicology. |
|  |  | 1. Waste can be a resource. |
|  |  | 1. Green chemistry is an approach to designing chemicals that avoids harming the environment and human health. |
|  |  | 1. Essential oils are found in nature and they evaporate easily. |
|  |  | 1. Traditional methods of obtaining essential oils from plants require a lot of energy. |
|  |  | 1. Many companies value green chemistry. |
|  |  | 1. Supercritical fluids have properties of both liquids and gases. |
|  |  | 1. Carbon dioxide is a liquid at low temperatures and pressure. |
|  |  | 1. Lesson plans have been developed to help elementary students learn about green chemistry. |

### Graphic Organizer

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

**Directions**: As you read the article, complete the graphic organizer below to analyze green chemistry principles.

|  |  |
| --- | --- |
|  | **Essential Oil Extraction** |
| **Uses of essential oils** |  |
| **Green process, including advantages** |  |
| **Traditional process and drawbacks** |  |
| **What do green chemists do? Give at least three examples.** | |

**Summary**: On the back of this paper, write a tweet (280 characters or less) about the importance of green chemistry, based on what you learned from reading the article.

### Student Reading Comprehension Questions

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

Name

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

* 1. What do students learn about molecules in a toxicology class that is different than what those students would learn about the same molecules in a typical chemistry class?
  2. What is the approach of green chemistry?
  3. In Kiara and Keirsi’s experiment, what caused the carbon dioxide gas to change to liquid?
  4. How were the essential oils extracted in the experiment?
  5. Why are essential oils fragrant?
  6. Why does the industrial process to obtain essential oils require a lot of energy?

**Student Reading Comprehension Questions, cont.**

* 1. (a) What was the initial focus of green chemistry, and (b) how did this eventually shift?
  2. Estimate from the graph the temperature at which solid CO2 would sublime if its pressure were reduced to 0.1 atmospheres.
  3. Give three criteria used for the materials produced for industry by green chemistry methods, as provided by the article.
  4. How is Beyond Benign advancing green chemistry education in K-12 classrooms?

**Critical-Thinking Question**

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

Considering the last three “wet” laboratory activities that you performed in class, suggest two ways that you could have “greened” any of the chemistry that you used.

### Answers to Reading Comprehension Questions

1. **What do students learn about molecules in a toxicology class that is different than what those students would learn about the same molecules in a typical chemistry class?**

Toxicology classes teach students about what happens when molecules interact with the environment and with our bodies, rather than just learning what molecules can do and how to make them.

1. **What is the approach of green chemistry?**

The approach of green chemistry is to design chemicals, chemical processes, and consumer products in ways to avoid harm to the environment and human health.

1. **In Kiara and Keirsi’s experiment, what caused the carbon dioxide gas to change to liquid?**

In Kiara and Keirsi’s experiment, the warm water caused the dry ice to sublime (change directly from solid to gas); as the gas pressure increased in the centrifuge tube, the extra pressure turned the carbon dioxide gas to liquid.

1. **How were the essential oils extracted in the experiment?**

The essential oils were extracted by the liquid CO2, which penetrates the zest and brings the essential oils out.

1. **Why are essential oils fragrant?**

Essential oils are fragrant because of their chemical makeup. They are complex mixtures that contain some volatile compounds that evaporate easily, releasing odors.

1. **Why does the industrial process to obtain essential oils require a lot of energy?**

The industrial process to obtain essential oils from plant material uses steam distillation at high temperatures, which requires a lot of energy.

1. **(a) What was the initial focus of green chemistry, and (b) how did this eventually shift?**

a. The initial focus of green chemistry was to clean up pollution after it had already been released.

b. The focus shifted to creating products that will degrade harmlessly rather than accumulate in the environment. (Accept this student answer: “… products that will degrade in water and sunlight, not accumulate in oceans”).

1. **Estimate from the graph the temperature at which solid CO2 would sublime if its pressure were reduced to 0.1 atmospheres.**

Solid CO2 will sublime at a temperature of –100 oC when its pressure is reduced to   
0.1 atmospheres.

1. **Give three criteria used for the materials produced for industry by green chemistry methods, as provided by the article.**

According to the article, three criteria used for the materials produced for industry by green chemistry methods are

1. cost,
2. safety, and
3. performance.
4. **How is Beyond Benign advancing green chemistry education in K-12 classrooms?**

Beyond Benign is advancing green chemistry education by creating free, online lesson plans for K-12 classrooms.

**Critical-Thinking Question**

**Considering the last three “wet” laboratory activities that you performed in your chemistry lab, suggest two ways that you could have “greened” any of the chemistry that you used.**

Student suggestions could include:

* Reduce the energy required by
* reducing the hot-plate temperature as soon as the required boiling temperature has been reached.
* considering the use of a solar oven for the experiment
* Reduce pollution by
* following suggested procedures from the teacher for safely neutralizing acid or base waste by-products.
* drying waste solutions to reduce volume.
* properly disposing of residual solids.
* placing environmental contaminants into specially labeled containers for professional disposal.
* Reduce chemical use by
* carefully measuring supplies.
* checking to see if distilled water is required or if tap water will work as well.

If student answers to the question above are discussed in class, the teacher might add to the discussion the following question: “In terms of green chemistry, what would be the advantages of *me*[the teacher] doing this lab activity as a class demonstration rather than *you* doing it in individual lab groups?”

Answers might include:

* Far fewer chemicals and smaller quantities of them might be needed—only one experiment instead of perhaps 10–12  
  (but the teacher might need a slightly larger amount than one student lab group’s amount to make it visible to the whole class).
* Less energy required for only that one reaction than for many.
* Safer because the teacher is in control of the reaction, flame, etc.
* Less waste after the reaction due to smaller amounts of chemicals used and produced.

It is *strongly recommended* that this follow-up question, for class discussion, be included.

“Ignoring green chemistry, what are some advantages of *you* [the students] doing the lab individually or in lab groups, rather than having *me* [the teacher] doing the lab as a demonstration?”

Student answers might include:

* Being able to *do* experiments myself is one of the main reasons I chose to take chemistry.
* Student-run experiments provide individual experiences for the student.
* I learn so much more from my handling the chemicals and equipment.
* The chemistry of the substances becomes so much more real to me when I actually *see* the reaction happening because I am the one doing it.
* I can’t see the reaction as clearly when you do it as a demonstration up front.

[Note: The student answers above are *critical* to the task of maintaining a student lab program when administrators so frequently—and adamantly—try to minimize that aspect of the chemistry curriculum.]

### *Standards and Vocabulary*

**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, 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.

**Vocabulary**

**Vocabulary** and **concepts** that are reinforced in the February/March 2019 issue:

Mixtures

Structural formulas

Environmental impacts of personal and societal decisions

Nanoparticles

Periodic properties

Phase changes

Green chemistry

* Consider asking students to read “Open for Discussion: Unpacking the Paleo Diet” on page 4 before they read “Making Sense of Milk” to learn why some people might choose not to consume dairy products.
* 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, and what they would like to explore further.
* Ask students if they have questions about some of the issues discussed in the articles.
* Encourage students to watch the videos and try the simulations suggested in some of the articles.

### *About the Guide*

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steven 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.

Christine Suh, *ChemMatters* editor, coordinated the production of the Guide. Lis Gallegos, *ChemMatters* editorial assistant, combined the Teacher’s Guides materials.

E-mail: [chemmatters@acs.org](mailto:chemmatters@acs.org)

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 or $135 for a site license. 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>.