



**April/May 2018**

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

**Teacher’s Guide**



**Teacher's Guide for**

### *“The Protein Myth: Getting the Right Balance”*

**April/May 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Energy** | While discussing heat measurement as calories or Joules in a lesson on specific heat capacity, students apply this to the measurement of the energy contained in foods expressed as Calories. The discussion of the difference between calories (c) and food calories (C) in the article supports this lesson. |
| **Thermochemistry** | The chemical potential energy content of food expressed as the kilocalorie (C) being converted to the kinetic energy used in the body can be used as one example while studying the heat changes of chemical reactions. |
| **Biochemistry** | Metabolic reactions of energy transfer involve the biomolecules of proteins, carbohydrates, and fats. Metabolism converts excess digestible food from any source, including protein, into fat. Students can keep this in mind as they examine their diet, possibly in a unit on food chemistry. |
| **Protein synthesis** | Proteins are polymers of long chains of amino acids. The illustration “How Your Body Uses Amino Acids as Building Blocks” in this article can help students visualize the primary, secondary, and tertiary structure of proteins while studying these biomolecules. |
| **Essential amino acids** | Not all plant proteins contain the same amino acids. From the list of essential amino acids in the article, students learn about the specific amino acids that must come from their diet. This is useful during a unit on food chemistry or protein synthesis. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5**: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, 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 April/May 2018 issue:

Food Chemistry

Structural Formulas

Chemical Reactions

Reaction Rates

Oxidation & Reduction

Distillation

Environmental chemistry

* Some of the articles in this issue provide information to help students consider their impact on the environment.
* Consider asking students to read “Open for Discussion: Weighing in on calories” to learn about calories in food prior to reading the article “The Protein Myth: Getting the Right Balance.”
* Students may find the infographic on page 19, “As a Matter of Fact: The Aroma of the Seaside” interesting after reading the article “Toxic Shorelines: The Science of Algal Blooms.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.

You might also ask them how information in the articles might affect their choices regarding food or water use. Also, ask them if they

# Reading Supports for Students

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

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

* **Anticipation Guide (p. 8):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

***NEW!!!***

Instead of using the Anticipation Guide, consider these ideas to engage your students in reading.

**The Protein Myth: Getting the Right Balance**

* Before reading, ask students to write 2-3 things they know about proteins, and one question they have about proteins.
* As they read the article, they can compare what they knew (or thought they knew) to the information in the article as they also search for answer(s) to their question.
* **Graphic Organizer (p. 9):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

* **Student Reading Comprehension Questions (p. 10-11):** 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 Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“The Protein Myth: Getting the Right Balance”, *ChemMatters*, April/May 2018

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

## Anticipation Guide

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

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Proteins are macronutrients needed to survive. |
|  |  | 1. Fats, proteins, and carbohydrates all provide the same number of calories per gram. |
|  |  | 1. According to the National Academy of Medicine, at least 50% of the calories we consume each day should come from protein. |
|  |  | 1. Teen athletes may need more protein than others. |
|  |  | 1. If you eat too much protein, it can be stored as fat. |
|  |  | 1. Avocado and nuts are healthy sources of fat. |
|  |  | 1. Both plant and animal proteins contain all 20 amino acids we need. |
|  |  | 1. Extra protein builds muscle. |
|  |  | 1. Egg whites and lean chicken are heart-healthy sources of protein. |
|  |  | 1. Nutrition experts claim that eating a variety of foods is healthier than using supplements. |

## Graphic Organizer

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

“The Protein Myth: Getting the Right Balance”, *ChemMatters*, April/May 2018

**Directions**: As you read, complete the graphic organizer below to describe proteins

|  |  |
| --- | --- |
| What are they?  Proteins | Why do we need them? |
| How should we choose which  proteins to eat? | What necessary foods are  NOT proteins? |

* Complete this graphic organizer to describe the best sources of protein.

|  |  |
| --- | --- |
| **Recommended Protein Sources** | **Advantages** |
|  |  |
|  |  |
| For vegetarians: |  |

**Summary:** On the back of this paper, write one new thing you learned about protein and a healthy diet that you would like to share with a friend who is concerned about his or her health.

“The Protein Myth: Getting the Right Balance”, *ChemMatters*, April/May 2018

## Student Reading Comprehension Questions

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

Name

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

* 1. Sarah and Anthony both increase what dietary component in their respective diets?
  2. What are macronutrients?
  3. What is a possible problem with Sarah and Anthony’s high protein diets?
  4. Compare the calorie content of the macronutrients—fat, proteins, and carbohydrates.
  5. What is the difference between “calorie” and “Calorie”? Which one is used to represent the energy content of the food we eat?
  6. What is an adequate daily amount of protein for teens?

**Student Reading Comprehension Questions, cont.**

“The Protein Myth: Getting the Right Balance”, *ChemMatters*, April/May 2018

* 1. Why do you need protein in your diet?
  2. What are some of the functions of proteins in the body?
  3. The body does not make all 20 of the amino acids it needs. List the nine amino acids that can only be acquired through diet.
  4. (a) Explain the difference between complete and incomplete protein sources, and (b) give examples of each.
  5. How can eating too much protein weaken bones?
  6. Describe how your body uses amino acids to produce proteins.

## Answers to Student Reading Comprehension Questions

1. **Sarah and Anthony both increase what dietary component in their respective diets?**

*Sarah and Anthony both increase their intake of protein in their respective diets.*

1. **What are macronutrients?**

*“Macronutrients are compounds that humans (and many other animals) need in their diets to meet their nutritional needs and provide the energy, or calories, they need to survive.”*

1. **What is a possible problem with Sarah and Anthony’s high protein diets?**

*Sarah and Anthony’s high-protein diets rely primarily on protein for their caloric needs, instead of food from several of the food groups that are a part of a balanced diet, so they may be missing out on the vitamins, minerals, and other nutrients needed to stay healthy.*

1. **Compare the calorie content of the macronutrients—fat, proteins, and carbohydrates.**

*Of the macronutrients fat, protein, and carbohydrates, fat contains nine food calories per gram while carbohydrates and proteins each contain four food calories per gram.*

1. **(a) What is the difference between “calorie” and “Calorie”?** **(b) Which one is used to represent the energy content of the food we eat?**
   1. *When lower case “c” is used in calorie, it represents a unit of measure that is defined as the amount of heat energy required to raise the temperature of one gram of water by one degree Celsius. When the upper case “C” is used, as in “Calorie”, it represents 1000 calories or a kcal. [Students may also find this information in this same issue of* ChemMatters *(April/May 2018) in the “Open for Discussion” article, entitled “weighing in on calories”, page 4.]*
   2. *The kcal or “Calorie” is used to express the energy content of food.*
2. **What is an adequate daily amount of protein (a) for teenage boys and (b) for teenage girls?**

*An adequate daily amount of protein for*

* 1. *teenage boys is 52 grams, while*
  2. *for teenage girls, it is 46 grams.*

1. **Why do you need protein in your diet?**

*Protein is important in the diet because it provides the 20 amino acids that the body uses to build new proteins in our body that keep us alive.*

1. **What are some of the functions of proteins in the body?**

*Proteins make up most of the physical structure of the body such as skin, hair, muscles, and organs. They also act as enzymes that catalyze reactions, enable the nerves to communicate, and help protect you from getting sick.*

1. **The body does not make all 20 of the amino acids it needs. List the nine amino acids that can only be acquired through diet.**

*The nine amino acids that can only be acquired through diet are:*

*1) histidine 2) leucine 3) tryptophan*

*4) valine 5) threonine 6) lysine*

*7) methionine 8) isoleucine 9) phenylalanine*

1. **(a) Explain the difference between complete and incomplete protein sources, and (b) give examples of each.**
   1. *A complete protein source is one that contains all of the essential amino acids needed by the body. An incomplete protein source only contains some of the essential amino acids.*
   2. *Animal proteins from eggs, milk, cheese, and meat are complete protein sources. Most plant sources lack some of the essential amino acids. Nuts, legumes, grains, fruits, and vegetables are incomplete protein sources that must be eaten in the correct combination to supply all nine essential amino acids.*
2. **How can eating too much protein weaken bones?**

*Eating too much protein can weaken the bones because, when protein is metabolized by the body, acid byproducts are released, which can lower blood pH and cause calcium to leach from the bones.*

1. **Describe how your body uses amino acids to produce proteins.**

*Individual amino acids join into a long strand called a peptide which, when increased in length, winds around itself to become a protein.*

# Possible Student Misconceptions

1. **“Since muscle is made of protein, if I want to build muscle I need to eat more protein.”** *Eating extra protein alone will not build muscle. To build muscle you need to do weight training. It is important to consume enough calories to fuel your weight training and extra exercise, but that can be done with normal or slightly increased amounts of protein and extra carbohydrates.* *Carbohydrates and fats can be stored in your muscles and used for energy during high-intensity workouts. Since your body cannot store protein, it is important to eat some protein after a workout to help the body build more muscle. Any extra protein that you eat above what your body can use is simply broken down and excreted by the kidneys. This is one reason that a high-protein diet can stress your kidneys. On the other hand, if you do not eat enough calories to fuel your exercise, then your body will break down muscle. Eating more protein without exercising will only cause you to gain weight in the form of fat.*
2. **“Protein is only in meat and animal products.”** *There are many plant sources of protein, too. Soy is a complete protein and is available as beans (edamame), soy milk, or as bean curd (Tofu). Quinoa is another plant product that is a complete protein. Other plant foods that are good sources of proteins, though not necessarily complete, are beans, peas, grains such as rice and oats, nuts, corn, avocados, spinach, broccoli, Brussels sprouts, and pumpkin seeds.*
3. **“Carbohydrates are bad for you.”** *Some diets encourage you to reduce the amount of carbohydrates in your diet to the extent that you may think carbohydrates are bad for you but, in the right amount, they are good for you. In fact, carbohydrates are the main source of fuel for the body where they are converted to the glucose required for all cells. The brain needs glucose, more than any other organ, to function properly. When you limit carbohydrates, you deprive your body of a main source of fuel and many essential nutrients that you need to stay healthy. Without enough carbohydrates, the body will use fat and protein for energy.*
4. **“All the essential amino acids must be eaten together during the meal in order to consume complete proteins from vegetable sources.”** *It used to be thought that each vegetarian meal needed to contain all nine essential amino acids in order to count as eating a complete protein. This myth can be traced to 1971 with the publishing of a book that advocated a vegetarian diet—“*Diet for a Small Planet”*. The author proposed pairing different vegetables based on their amino acid content, in order to ensure all nine essential amino acids would be consumed, eliminating the need for meat-based products. After multiple studies, it has been found that, if a variety of vegetables are consumed through the course of the day, they do not all have to be consumed in the same meal in order to supply the daily requirement for the essential amino acids. (*[*https://www.forksoverknives.com/the-myth-of-complementary-protein/#gs.QwfV3zk*](https://www.forksoverknives.com/the-myth-of-complementary-protein/#gs.QwfV3zk)*).*
5. **“Protein is protein. There isn’t any difference between the protein in a supplement and the protein in a normal diet.”** *Proteins are all different, based on their amino acid content. Some proteins contain all 20 of the amino acids the body uses to build its specific proteins, while some only contain a few amino acids. A person eating a varied diet will consume all the necessary amino acids. The amino acids that are present in protein supplements depend on the source of the protein used to make the supplement and how it is prepared. Whey protein is used for lots of protein supplements. It is the liquid portion of milk and contains 18 amino acids. It is particularly rich in the amino acid leucine. Leucine is the amino acid that is the gatekeeper to the muscle-building process. Twenty grams of whey protein contains 1.8 grams of leucine, which is the amount needed to initiate muscle growth. Proteins are compared based on the amount of leucine they contain. According to Alan Flanagan in “5 Common Myths About Protein”,*

To get 1.8 grams of leucine from lean beef, you’d need to eat 113 grams, which would include a total of 30 grams of protein. If you prefer brown rice protein, you’d have to eat about 48 grams of it to get your leucine quota. In short, the limit of how much protein you could or should eat has more to do with how much of that protein it takes to get 1.8 grams of leucine, not how much actual protein you eat.”

*(*[*https://www.bodybuilding.com/content/5-common-myths-about-protein.html*](https://www.bodybuilding.com/content/5-common-myths-about-protein.html)*)*

1. **“Eating fat is bad for you.”** *Actually, not eating fat is bad for you. You cannot live without some fats. Fat is one of the three macronutrients and is as important as protein and carbohydrates. The following are some of the important functions of fats in the body:*

* *Fats provide the essential fatty acids (similar to the essential amino acids).*
* *Cell membranes are made from lipids (remember the phospholipid bilayer you learned about in biology class?).*
* *The structural backbone of hormones is the fat, cholesterol.*
* *Many of the brain’s structural components are fat.*
* *The outer covering of nerve cells, the myelin sheath, is composed of fat.*
* *Some components of the immune system are fat based.*
* *Fat-soluble vitamins are stored in fat until the body needs them.*
* *Fats are a great source of energizing fuel.*
* *Fats make you feel full so you eat less food.*
* *Fats keep the skin soft.*

*So, you see, fats have many important functions and it would be unhealthy to eliminate them from your diet. That being said, there are different types of fats, some of which are better than others for your health. Saturated fats are comprised of single-bonded hydrocarbon chains. They are called “saturated” because all four bonding sites of every carbon atom in the chain is bonded to one other element. Examples of saturated fats are animal fats, butter, and cheese. Unsaturated fats are made up of hydrocarbon chains where there is at least one double/triple bond in the carbon chain. These fats are typically liquid at room temperature, like olive oil, safflower oil, corn oil, and nut oils. The third type of fat—and the one you want to avoid eating—is* trans *fat. These are primarily industrially-produced fats that are made by hydrogenation (adding hydrogen to the double- or triple-bonded carbon atoms in the hydrocarbon chain) of an unsaturated fat, to make it a solid at room temperature. These can be found in some margarines and in many processed foods.*

*In choosing the fats for your diet, choose unsaturated fats first, some saturated fats second, and avoid processed fats like trans fats.*

*(*[*https://www.health.harvard.edu/staying-healthy/the-truth-about-fats-bad-and-good*](https://www.health.harvard.edu/staying-healthy/the-truth-about-fats-bad-and-good)*)*

# Anticipating Student Questions

1. **“What are the Atkins and Paleo diets?”** *The Atkins and Paleo diets are both diets that restrict carbohydrates while allowing more protein and fat to take its place. They are both referred to as ketogenic diets. When the body has to break down fat for its energy, the liver will convert fat into fatty acids and ketone bodies. In some situations, the cells will use the ketone in place of glucose. Excess ketone is excreted in the urine.  
   The Atkins diet was founded by Dr. Atkins, a cardiologist. It restricts carbohydrate intake, while not restricting protein or fat. Protein and fat use more calories to process, so he claimed that eating these foods help burn more calories. The limited amount of carbohydrate eaten should be non-processed, so he recommends fresh vegetables instead of bread, pasta, and chips.  
   The Paleo diet is very similar, in that processed foods are not allowed. It is based on a diet similar to a caveman. It promotes the mantra, “If a caveman didn’t eat it, then neither should you.” In the Paleo diet, all grains are eliminated, as well as corn. It is a gluten- and lectin-free diet, both of which are high in wheat, rye, and barley. Sugar is forbidden, as are all processed foods. On this diet, you can eat meats, fish, nuts, leafy greens, regional vegetables, and seeds. Usually, milk and milk products are not eaten with this diet, but some variations will allow these to be added back in slowly after they have been eliminated for a while. Some people prone to food allergies may be prescribed a paleo diet.*
2. **“Are there other macronutrients besides proteins, fats, and carbohydrates?”** *Proteins, fats, and carbohydrates are the nutrients our bodies need in the greatest amounts for our energy. Their energy content is measured in calories, and some sources will only list these three as macronutrients. However, our bodies also need water and fiber in large quantities to function properly, so many sources consider these macronutrients as well.*
3. **“If there are *macro*nutrients, there must be *micro*nutrients, too. What are they, and what do they do for us?”** *The micronutrients are the vitamins and minerals that we need only in minute amounts in our diets. They do not provide energy, but they enable many chemical reactions that occur in the body to help regulate cell function. Iron, for example, is complexed with proteins to form the larger molecule hemoglobin.  
   Vitamins are organic (carbon-containing) compounds that can be changed by heat, oxygen, light, and chemical processes. Therefore, a food’s vitamin content may change depending on how the food is altered before you eat it. The water-soluble vitamins are vitamins B1, B2, B6, B12, C, niacin, and folic acid. When excess amounts of these vitamins are consumed, they are excreted in the urine, so they need to be consumed daily. The water-insoluble, or fat-soluble, vitamins can be stored in the fatty tissues of the body when in excess. Because they can be stored, fat-soluble vitamins can become toxic if taken in large quantities. The fat-soluble vitamins are Vitamins A, D, E, and K.  
   Minerals are inorganic substances that are found in the soil or water and are absorbed by plants, which are then eaten by animals and humans. Minerals exist in their simplest chemical form as ionized elements and are not destroyed by heat or light. The mineral content of plants varies with the soil content and the maturation of the plant. The major minerals are calcium, potassium, sodium, chloride, phosphorus, sulfur and magnesium. The body requires more than 100 milligrams of these per day. The minerals that are required in quantities less than 100 milligrams a day are referred to as “trace minerals”. The trace minerals are iron, copper, zinc, cobalt, chromium, selenium, iodine, manganese, molybdenum, and fluoride. (*[*http://www.innerbody.com/nutrition/micronutrients#major-minerals*](http://www.innerbody.com/nutrition/micronutrients#major-minerals)*)*
4. **“What exactly could happen to me if I eat too much protein?”** *(1) If you eat more protein than your body can use, some would be converted and stored as fat, and the excess nitrogen would be excreted by the kidneys. (2) When proteins are broken down into fatty acids and ketones, the buildup of ketones will give you bad breath and an unpleasant body odor. (3) Some people experience bowel problems, either in the form of constipation or diarrhea, often times due to the lack of fiber in the diet. (4) When the protein is broken down, the nitrogen products must be flushed from the body and, often, water that is needed elsewhere is used for this, causing you to become dehydrated. (5) If your protein source is red meat, then there is an increased risk you may develop heart disease and/or cancer. This increased risk is not seen in persons whose primary source of protein, even in excess, is from plants.*
5. **“What are some of the vegetable combinations that provide complete proteins?”** *Some examples of vegetable combinations that together provide all nine essential amino acids are rice and beans, lentils and barley, peanut butter with whole wheat bread, and beans and cornbread.*
6. **“How does eating too much red meat cause disease?”** The mechanisms at work that lead *people who eat a lot of red meat to develop heart disease or cancer* are *not completely understood, but scientists have made some suggestions for the causes. Red meat is high in saturated fats, which raise blood cholesterol. The excess cholesterol can build up in the arteries and restrict blood flow to the heart, causing heart disease. There is a strong correlation between a diet that includes a lot of red meat and heart disease. There is also a significant correlation between diets high in saturated fats and an increased risk of colon cancer and breast cancer. There is not as strong a correlation between eating red meat and cancer, but several research studies have shown an increased risk for colorectal cancer in persons who have a diet rich in red meat and processed meats like bacon, ham, sausage, and hot dogs. When meat is grilled at high temperatures heterocyclic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs) are formed in the meat. Eating these compounds increases the risk of cancer. Well-done meat contains more of these compounds than meat that is not cooked as long. So, if you love grilled meat, you may try grilling it at a lower temperature, avoid allowing any juice to fall on the coals, and avoid overcooking it. (*[*https://www.webmd.com/food-recipes/features/the-truth-about-red-meat#1*](https://www.webmd.com/food-recipes/features/the-truth-about-red-meat#1)*)*
7. **“What happens to proteins in the body?** *In the body, the digestion of proteins begins in the stomach. Hydrochloric acid in the stomach maintains a pH of 1.5–3.5, which denatures the protein, while the enzyme pepsin cuts the denatured protein into smaller polypeptides and individual amino acids. In the small intestine the pancreas secretes bicarbonate, to neutralize the acid, and more digestive enzymes, to break down the polypeptides into individual amino acids. The amino acids are transported across the intestinal mucosa to the liver and cells throughout the body, to create new proteins, or to be converted into fats or acetyl Co A needed for the Krebs cycle. When there are excess amino acids, they undergo decomposition, which results in hydrocarbons and ammonium ions. A high concentration of nitrogen is toxic. The body’s urea cycle uses to ammonium ions to make urea, which can then be excreted from the body. (*[*https://opentextbc.ca/anatomyandphysiology/chapter/24-4-protein-metabolism/*](https://opentextbc.ca/anatomyandphysiology/chapter/24-4-protein-metabolism/)*)*
8. **“How do they make protein powder? What else is in it?”** *There are a variety of different protein powders on the market, and their preparation and content depend on the source. Whey protein is one of the most popular and least expensive. It is made from the liquid portion of milk. There are three types of whey powder—concentrate, isolate, and hydrolysate. Protein concentrates have some fats and carbohydrates and may contain 30% to 90% protein. Whey protein isolates have the lactose and fat removed and are at least 90% protein. Whey hydrolysate has been partially digested and is more easily absorbed. This is the form that is used in baby formulas. Casein is the solid protein in milk when the whey is removed. Both casein and whey have the same protein profile (same amino acids) and both are sold as protein powders. Whey is absorbed quickly by the body, while casein takes longer to digest. It is best to use casein powder before going to bed. Egg protein is rich in vitamins and minerals and as a powder is slightly more expensive than whey and casein protein. Soy protein powders are also an economical source of complete protein. Protein powders prepared from hemp seeds are among the most vegan-friendly of the complete protein powders. Since hemp is only harvested in mass quantities in select countries because of its association with cannabis, it is the most expensive of all the protein powders.* ([*https://www.medicalnewstoday.com/articles/263371.php*](https://www.medicalnewstoday.com/articles/263371.php)*) (*[*https://greatist.com/fitness/protein-supplement-nutrition-guide*](https://greatist.com/fitness/protein-supplement-nutrition-guide)*)*

# Activities

**Labs and demos**

**“Food Calorimetry: How to Measure Calories in Food”:** Students learn how to use a soda-can calorimeter to determine the calorie content of a variety of foods. The procedure includes pictures that illustrate several steps, so students will know exactly how to set up their calorimeter. (<https://www.carolina.com/teacher-resources/Interactive/food-calorimetry+/tr23949.tr>) Another source for this activity can be found here: <https://www.flinnsci.com/api/library/Download/f9560a5fc7ef4a6b8f4598fea30626eb>.

**“Presence of Protein in Food (Qualitative Analysis)” (30 min):** This, the 4th experiment in a set of six experiments in “Food Science Experiments to Support the Teaching of Science and Technology” uses Biuret reagent to test for the presence of protein in a variety of different foods. When food samples are tested, the difference in color between deep purple and lighter pink shows students the qualitative difference between a high-protein concentration and a protein source consisting primarily of short-chain polypeptides. (<http://www.nzifst.org.nz/careers/secondaryresources.asp>)

“**Denaturing Proteins”:** In this short laboratory experiment, students explore how heat, acids and bases, organic compounds, and heavy metals denature proteins. In six different test tubes, students test the effect of adding heat, salt, acid, base, alcohol, or a heavy metal salt to a sample of egg white. (<http://www.math.unl.edu/~jump/Center1/Labs/DenaturingProteins.pdf>)

**Simulations**

“**Eating and Exercise” (PhET):** Students can calculate their body mass index (BMI) and enter their activities and diet to determine if they are heart healthy. The app graphs the projected weight change over time, based on the diet and exercise activities the student chooses. (<https://phet.colorado.edu/en/simulation/legacy/eating-and-exercise>)

**Calorimetry experiments:** This simulation provides students the opportunity to conduct a variety of virtual calorimetry experiments, where they can manipulate the variables of mass, temperature, and type of substance (liquid, solid, solution), and observe how changing the variable affects the amount of heat exchanged in a constant-pressure calorimeter. (<http://dbpoc.com/pearson/chemsims/gold/calorgold5/Calor.php>)

**Proteins and their synthesis:** The “Protein & DNA” simulation at the *Molecular Workbench* Web site, which contains maneuverable molecular models, would be useful during a unit on protein structure and composition; the first six lessons pertain to proteins as polymers of amino acids and how the shape of the protein is determined by the amino acids and their sequence. The Web site index can be found here: <http://mw.concord.org/modeler/>; search for “Proteins and DNA” among the icons. You will need to download the Molecular Workbench software and Java software to use the simulation. (Molecular Workbench is a worthwhile site that has many biology, chemistry, and physics simulations, somewhat similar to PhET.)

**Media**

**“How Does Protein Build Muscle?” video (3:40):**  This video describes how muscles grow in response to exercise, and it reviews the protein requirements for muscle growth in athletes and non-athletes. Protein powders are depicted as one way to increase protein intake. (<https://www.youtube.com/watch?v=L5-tKciXEG8>)

**“7 Warning Signs Your Body Needs More Protein that You Shouldn't Really Ignore” video (3:22):** This short video helps students know if they are protein deficient, by going over seven symptoms of protein deficiency. It also reviews the average daily requirement for protein and gives examples of several foods rich in protein. (<https://www.youtube.com/watch?v=0s0WXiSd3dQ>)

**Lessons and lesson plans**

**Isolation and testing of milk proteins:** “Unit 3: Proteins” from *Food Chemistry Experiments* contains background information about proteins for students and teachers. In the laboratory activity, students isolate milk proteins by three different methods, test them for protein using a biuret test, and complete an accompanying worksheet. (<https://naitc-api.usu.edu/media/uploads/2017/06/16/experiments_foodscience.pdf>)

**“Protein: Complete and Incomplete”:** This lesson plan contains background information concerning complete and incomplete proteins and provides five options for the presentation of the lesson. Students can take notes and complete a study guide, examine a variety of foods and record their protein content in “Protein Hunt”, record their daily intake of protein by keeping and analyzing a food diary, and/or taste and prepare foods, like tofu, with high protein content. (<https://www.uen.org/lessonplan/view/1269> )

**Projects and extension activities**

**Graph protein content, experiment with fat content, or make tofu burgers:** In “Unit 2 - Lipids and Proteins”—of the *Food Science Curriculum*—students analyze the nutritional components in a variety of meat sources listed on a nutritional information chart and prepare a bar graph of the information. In a lab activity, students measure the amount of fat in a variety of meat sources, while a cooking activity introduces students to tofu as an alternative source of protein, by having them make tofu burgers. (<https://www.isbe.net/Documents/fcs_guide.pdf>)

# References

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

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



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

Available Now!

In “Hold the Meat”, author Nolte writes about how to get protein in your meals while on a vegetarian diet. After presenting the need for proteins and their chemical composition, she discusses the most popular protein-containing meat substitutes on the market. (Nolte, B. Hold the Meat. *ChemMatters*. 2011, *29* (4), pp 9–11)

The Teacher’s Guide for the December 2011 *ChemMatters* Nolte article above provides additional information on protein function, structure, and synthesis. Several classroom activities are described, including a lab for the separation of an amino acid mixture by paper chromatography.

“Sports Supplements: Helpful or Harmful?” contains a discussion about the use of whey protein powder as a dietary supplement to build muscle. The supplements creatine and L-arginine are also discussed. (DeAntonis, K. Sports Supplements: Helpful or Harmful? *ChemMatters*. 2013, *31* (3), pp 12–14)

The Teacher’s Guide for the October 2013 *ChemMatters* DeAntonis article above contains extensive information about whey protein used as a dietary supplement, as well as information about the lack of regulation of dietary supplements. It presents extensive information that discourages the use of these supplements by teenagers.

# Web Sites for Additional Information

**Dietary requirements for protein**

The USDA site ChooseMyPlate.gov contains several tables giving the recommended dietary allowance for protein based on age and gender. This is an excellent source for information about foods and their nutritional content, including vegetarian choices. (<https://www.choosemyplate.gov/protein-foods>)

In “How Much Protein Do You Really Need to Eat?”, Sheela Prakash, a food editor and registered dietician, explains how to calculate your daily protein requirements based on factors specific to your lifestyle. (<https://www.thekitchn.com/how-much-protein-do-you-really-need-243520>)

The above link is one of the 11 segments of *Protein 101*, which attempts to educate about dietary protein. Some of the topics presented are the amount of protein needed if you’re working out, ways for vegetarians to fulfill their protein requirements, and common myths surrounding protein, as well as multiple examples of different foods and their protein content. (<https://www.thekitchn.com/search?q=Protein+101>)

**Whey protein**

This site answers these questions: What is whey protein? Do whey supplements work? Are whey supplements safe? The article cites several studies, including one done on Marines during basic training, to provide evidence for its claims about whey supplements. (<https://www.livescience.com/45120-whey-protein-supplements.html>)

The article “What are the Benefits and Risks of Whey Protein?” not only discusses the benefits, side effects, and potential risks of using whey protein supplements, but it also describes three different types of whey protein supplements. (<https://www.medicalnewstoday.com/articles/263371.php>)

**Protein powders and protein bars**

This site compares the difference in protein uptake from liquid protein shakes vs solid protein bars. One study comparing solid protein bars to liquid protein shakes found that the participants consuming the liquid protein registered higher levels of amino acids in their bloodstream 30 minutes and four hours after consumption. (<https://www.livestrong.com/article/462471-protein-bar-vs-powder/>)

**Protein synthesis**

A brief outline of how proteins are chemically synthesized in the lab can be found here: <http://resources.schoolscience.co.uk/unilever/16-18/proteins/Protch4pg1.html>.

This site is an animation that shows how every protein molecule of an organism is synthesized by that organism in a prescribed process, using DNA, mRNA, and amino acids. This activity helps students understand how proteins are made in the human body. (<https://www.wisc-online.com/learn/natural-science/life-science/ap1302/protein-synthesis>)

**Essential amino acids**

The article “Which Amino Acids are Contained in Milk and Eggs?” presents information about the nine essential amino acids, four non-essential amino acids, and the eight semi-essential amino acids, and which ones are contained in milk and eggs. While milk and eggs are considered complete proteins, they do not contain all the amino acids the body uses to make protein. (<http://healthyeating.sfgate.com/amino-acids-contained-milk-eggs-3992.html>)

Some sources will include arginine in the list of essential amino acids because it is required in the diet for young children, but it is not needed in the adult diet. This site shows the structural formulas for the 10 essential amino acids.

(<http://hyperphysics.phy-astr.gsu.edu/hbase/Organic/essam.html>)

**Plant sources of protein**

“The 20 Highest Protein Veggies (And Other Plant-based Foods) You Can Eat” not only lists 20 plant-based foods with high protein content, it also gives recipes for dishes using some of them. (<https://www.prevention.com/eatclean/high-protein-vegetables-and-plant-based-food>)

“26 Delicious Vegan Sources of Protein” discusses the myth of protein combining and ways to “rethink” protein, before going through a pictorial list of 26 vegan-friendly foods with high protein content. Some recipe links are provided with most of the foods. (<http://www.onegreenplanet.org/vegan-food/vegan-sources-of-protein/>)

**Macronutrients & micronutrients**

This article discusses micronutrients, dividing them into specific categories of   
water-soluble and water-insoluble vitamins, and major and trace minerals. It discusses the recommended intake, the food sources containing the nutrient, and the effects on the body of getting too much or too little of the nutrient. (<http://www.innerbody.com/nutrition/micronutrients>)

A brief description of the macronutrients and micronutrients that are part of the food pyramid’s essential nutrients can be found here: <http://www.fao.org/elearning/Course/NFSLBC/en/story_content/external_files/Essential_Nutrients.pdf>.

**Health problems caused by eating too much protein**

The article “Are There Risks Associated with Eating Too Much Protein?” reviews some of these risks and mentions the sources of protein that prove the most problematic. (<https://www.healthline.com/health/too-much-protein>)

“The Truth about Red Meat” citesseveral research studies concerning the risk factors from eating too much red meat. Heart disease and cancer are not the only diseases that studies show to have a correlation with a diet rich in red meat.

(<https://www.webmd.com/food-recipes/features/the-truth-about-red-meat#1>)



**Teacher's Guide for**

### *“The Story Behind Defective Airbags”*

**April/May 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Reaction rates** | While studying the factors that affect the rate of a reaction, you can use the change in state of ammonium nitrate in compromised airbags to illustrate how a change in physical state (solid to solution—and back again) and surface area (pellets cracked, making smaller particles, possibly even powder) caused the unexpected increase in reaction rate in the TAKATA airbags. |
| **Gas properties** | The compressibility of gas is the property most responsible for the effectiveness of airbags reducing injuries in crashes. The air inside the bag compresses when the bag is hit by a body. This can be pointed out when introducing the properties of a gas. |
| **Gas laws** | The airbag reactions would be good examples to use while studying gas laws. The Ideal Gas Law is useful in calculating the moles of the gas required to inflate the airbags to a predetermined volume and pressure. |
| **Stoichiometry** | Calculating the amount of sodium azide or other gas-generating reactant needed to fully inflate an airbag is a useful example for a stoichiometry problem. |
| **Decomposition reactions** | The reactions mentioned in the article that produce the gas for the airbags are decomposition reactions. These could be used as examples while teaching a unit on types of chemical reactions. |
| **Reaction kinetics** | All of the reactions that are used to inflate airbags, once initiated, occur at astounding speeds. These reactions could be used while studying reaction kinetics. |
| **Green chemistry** | Airbags using sodium azide (NaN3) include KNO3, to react with the elementary sodium produced in the reaction; and SiO2, to convert the alkali metal oxides produced in the azide reaction to a silicate glass, all of which makes the final products of the reaction more environmentally friendly. This is an example of respecting the principles of Green Chemistry during the design of a product. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5**: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, 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 April/May 2018 issue:

Food Chemistry

Structural Formulas

Chemical Reactions

Reaction Rates

Oxidation & Reduction

Distillation

Environmental chemistry

* Some of the articles in this issue provide information to help students consider their impact on the environment.
* Consider asking students to read “Open for Discussion: Weighing in on calories” to learn about calories in food prior to reading the article “The Protein Myth: Getting the Right Balance.”
* Students may find the infographic on page 19, “As a Matter of Fact: The Aroma of the Seaside” interesting after reading the article “Toxic Shorelines: The Science of Algal Blooms.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their choices regarding food or water use. Also, ask them if they have questions about some of the issues discussed in the articles.
* The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.

# Reading Supports for Students

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

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

* **Anticipation Guide (p. 31):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

***NEW!!!***

Instead of using the Anticipation Guide, consider these ideas to engage your students in reading.

**The Story Behind Defective Airbags**

* Before reading, ask students to describe how they think airbags work, including how they inflate, then compare their ideas to the information in the article.
* Ask students what questions about airbags they would like to have answered in the article.
* **Graphic Organizer (p. 32):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

* **Student Reading Comprehension Questions (p. 33-34):** The Student Reading Comprehension Questions are designed to encourage students to read the article (and graphics) for comprehension and attention to detail, to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment, and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.

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 Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“The Story Behind Defective Airbags”, *ChemMatters*, April/May 2018

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

## Anticipation Guide

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

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Almost all of the defective airbags manufactured by the Takata Corporation have been replaced. |
|  |  | 1. Frontal airbags reduce fatalities only when used with seat belts. |
|  |  | 1. Airbags have sensors that detect rapid deceleration. |
|  |  | 1. To inflate an airbag, a tank containing air at high pressure releases its content. |
|  |  | 1. The airbag should be deflating when it contacts a person’s head or torso. |
|  |  | 1. A typical sodium azide airbag generates 70 liters of nitrogen gas at standard temperature and pressure. |
|  |  | 1. Sodium azide is nontoxic. |
|  |  | 1. Ammonium nitrate is unaffected by temperature changes or moisture. |
|  |  | 1. Greater surface area of reactants in airbags produces gas faster. |
|  |  | 1. The chemicals used in airbags all contain nitrogen. |

## Graphic Organizer

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

“The Story Behind Defective Airbags”, *ChemMatters*, April/May 2018

**Directions**: ***As you read***, complete the graphic organizer below to describe the chemicals and chemical reactions used in airbags.

|  |  |  |  |
| --- | --- | --- | --- |
| **Chemicals** | **Formula** | **Chemical Reaction in Airbags** | **Drawbacks** |
| **Sodium azide** |  |  |  |
| **Ammonium nitrate** |  |  |  |
| **Guanidine nitrate** |  |  |  |

**Summary:** In the space below, or on the back of this paper, write a short explanation of why the Takata airbags were defective, including the chemicals used.

## Student Reading Comprehension Questions

“The Story Behind Defective Airbags”, *ChemMatters*, April/May 2018

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

Name

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

* 1. From 1987 through 2015, how many lives are estimated to have been saved by airbags?
  2. How have airbags changed in regards to their activation system?
  3. How are airbags inflated?
  4. In order to adequately protect the occupant of a vehicle involved in a crash, how much time does the airbag have to deploy?
  5. How long does an airbag remain inflated before it starts to deflate?
  6. Why should an airbag be deflating, instead of inflating, when the head or torso hits it?

**Student Reading Comprehension Questions, cont.**

“The Story Behind Defective Airbags”, *ChemMatters*, April/May 2018

* 1. Besides sodium azide (NaN3), what two other substances are included in this type of airbag, and what is the purpose for each?
  2. How much nitrogen does the reaction in a typical airbag generate at standard temperature and pressure?
  3. What is one of the drawbacks to using sodium azide in airbags?
  4. What is the chemical reaction that inflated the airbags manufactured by Takata?
  5. What was causing the canisters in the airbags made by Takata to explode?
  6. Since the problem with the Takata airbags, what chemical reaction is now being used to generate the gas needed to inflate an airbag?

## Answers to Student Reading Comprehension Questions

1. **From 1987 through 2015, how many lives are estimated to have been saved by airbags?**

*From 1987 through 2015, the addition of frontal airbags to cars saved an estimated 44,869 lives.*

1. **How have airbags changed in regards to their activation system?**

*Newer airbags contain electronic accelerometers contained within a microchip, while the older airbags relied more on a mechanical system made up of springs or magnets connected to a metal ball. When the car’s brakes were applied, the metal ball broke free and activated an electronic sensor.*

1. **How are airbags inflated?**

*Airbags are inflated as the result of a very rapid chemical reaction.*

1. **In order to adequately protect the occupant of a vehicle involved in a crash, how much time does the airbag have to deploy?**

*An airbag must deploy in 40 milliseconds or less to protect the occupant of a vehicle involved in a crash.*

1. **How long does an airbag remain inflated before it starts to deflate?**

*An airbag starts to deflate immediately after it is inflated.*

1. **Why should an airbag be deflating, instead of inflating, when the head or torso hits it?**

*The airbag should be deflating instead of inflating when a body hits it because a deflating airbag provides more cushioning to the body or head than an inflating airbag does.*

1. **Besides sodium azide (NaN3), what two other substances are included in this type of airbag (uninflated), and what is the purpose for each?**

*Two other substances included in a sodium azide airbag are:*

* 1. *Potassium nitrate (KNO3)—converts the sodium produced in the reaction to less harmful products and produces more nitrogen to further inflate the airbag,*
  2. *Silicon dioxide—converts the toxic byproducts potassium oxide (K2O) and sodium oxide (Na2O) into inert silicate glass.*

1. **How much nitrogen does the reaction in a typical airbag generate at standard temperature and pressure?**

*The typical airbag generates 70 liters of nitrogen gas at standard temperature and pressure.*

1. **What is one of the drawbacks to using sodium azide in airbags?**

*One of the drawbacks to using sodium azide in airbags is that sodium azide is about as toxic as cyanide compounds and can cause serious health conditions in persons exposed to it.*

1. **What is the chemical reaction that inflated the airbags manufactured by Takata?**

*The thermal decomposition of ammonium nitrate into water vapor and nitrous oxide is the reaction that Takata used to inflate the airbags that eventually were recalled.*

1. **What was causing the canisters in the airbags made by Takata to explode?**

*The canisters that held the ammonium nitrate exploded when the ammonium nitrate within them had been physically changed in a way that caused the reaction to proceed faster than the airbag designers intended. Those changes happened when the ammonium nitrate was exposed to moisture that dissolved some of the ammonium nitrate or to temperature changes that caused the ammonium nitrate pellets to crack into smaller pieces. Both changes increase the reaction rate such that the gas cannot be released into the airbag fast enough, and so pressure builds up inside the canister itself until it explodes.*

1. **Since the problem with the Takata airbags, what chemical reaction is now being used to generate the gas needed to inflate an airbag?**

*The decomposition of guanidine nitrate [C(NH2)3]NO3 is the reaction used by most companies that currently produce airbag inflators.*

*[Students may give the reaction as*

*[C(NH2)3]NO3 (s) 🡪 3 H2O (g) + 2 N2 (g) + C (s).]*

# Possible Student Misconceptions

1. **“During a crash, the driver would be protected by an inflating airbag, not a deflating airbag.”** *When a car suddenly stops, the persons in the car continue to travel forward. An airbag prevents the driver from hitting the steering wheel or windshield during this forward motion. If the airbag is inflating, the person will be hit by an object that is traveling toward them at a speed of 200 mph. When the airbag is deflating it becomes like a pillow that can be compressed by a person’s body. (*[*https://www.popsci.com/how-airbags-are-supposed-to-work*](https://www.popsci.com/how-airbags-are-supposed-to-work)*)*
2. **“It is not as important to use my seat belt because the airbags will stop me from being thrown forward during a collision.”** *Actually, it is the seat belt that keeps your body from being thrown forward during a collision*. *Airbags and seat belts used together help protect you during a crash. The seat belt keeps the driver in the seat, while an airbag simply protects the head by keeping it from hitting the steering wheel, dashboard, or windshield. For airbags to work the way they are intended, the drivers and passengers must be using their seat belts correctly. Airbags that are standard equipment on all cars are designed for frontal crashes and are activated by a sudden impact of 12 miles per hour or more. These airbags do not protect the driver in rear-impact, side-impact, or rollover crashes, while a seat belt will help protect the driver and passengers in these types of accidents. Some cars are equipped with additional airbags that help prevent injuries in side-impact crashes and rollovers but these airbags also are designed for passengers who are using a seat belt.*
3. **“I was in an accident once where the airbag went off and the car filled up with smoke afterward. I thought the car was catching on fire.”** *This most likely was a talc powder instead of smoke. Airbags contain talc or a corn-based powder inside to ensure that the airbag unfolds smoothly when it is deployed. As the airbag deflates, the powder can be seen floating throughout the car. The powder is non-toxic and should not harm the persons inside the car. An exception would be persons with asthma or other breathing problems where the lungs are compromised. It is an interesting side effect that persons who have been in a car when the airbags deployed will test positive for blood alcohol on a breathalyzer test that is given immediately after the accident. The small particles of powder remain in the lungs for a while and are present in the breath, making the breath a colloid. When the person blows into a breathalyzer that uses infrared light shown through the sample chamber, the light is scattered due to the Tyndall effect, and the results of the test will be falsely elevated. In this situation, a blood test is the best method for securing an accurate blood alcohol level. (*[*http://gaduiblog.com/2006/08/07/breath-test-after-airbag-deployment/*](http://gaduiblog.com/2006/08/07/breath-test-after-airbag-deployment/)*)*
4. **“I heard that if your car is 10 years old or older you should probably have the airbags replaced.”** Unless it deploys in a crash, an a*irbag is designed to be maintenance free for the life of the vehicle. Some manufacturers put a date stamp on the bags for a while that said to check after 10 or 15 years but that is generally not considered necessary anymore. Airbags have a warning light that should come on if there is a problem with the wiring to the airbag. In 1992, the Insurance Institute for Highway Safety conducted a demonstration test on the original frontal airbags of a 1973 Chevrolet Impala, one of the first 1,000 cars equipped with an airbag. Even though the clock and radio no longer worked and the car had over 100,000 miles on the odometer, the airbags deployed properly, when the car was driven into a barrier at 25 mph. (*[*https://www.autoblog.com/2013/07/30/should-car-owners-replace-airbags-in-older-cars/*](https://www.autoblog.com/2013/07/30/should-car-owners-replace-airbags-in-older-cars/)*)*

# Anticipating Student Questions

1. **“How do they adjust the force that expands an airbag?”** *The force with which an airbag inflates is due to the pressure exerted by the amount of gas that is generated by the chemical reaction in a short amount of time. This can be adjusted by the amount of gas-generating compound, such as sodium azide, tetrazole, or ammonium nitrate that is used. It is a stoichiometry problem and an ideal gas law problem combined. If you know the volume of the airbag at full inflation and you calculate the desired pressure in the bag when inflated with a gas traveling at a speed of 200 mph, you can calculate the amount of gas (in moles) required using the Ideal Gas Law. From here, it becomes a stoichiometry problem where you solve for the number of grams of the gas-generating compound required to produce the calculated number of moles of nitrogen gas. (*[*http://www.chemistry.wustl.edu/~edudev/LabTutorials/Airbags/airbags.html*](http://www.chemistry.wustl.edu/~edudev/LabTutorials/Airbags/airbags.html)*)*
2. **“Why haven’t all the airbags that have been recalled been replaced?”** *There are several factors that are affecting the number of cars being returned to the dealer to have airbags replaced. Some car owners do not know about the recall or have not received notification that their car has an airbag that should be replaced. Many who have received notice, have not acted upon it. In implementing the recall, the National Highway and Transportation Safety Administration (NHTSA) has subdivided the United States into three zones according to the weather. NHTSA has ordered manufacturers to replace the inflators in the oldest cars, equipped with the faulty inflators, located in warm humid states like Florida and Alabama before replacing them in newer cars garaged in states with moderate or cold climates. Zones with high temperature and humidity have been given priority because those are the conditions that cause the ammonium nitrate in the airbag initiator to deteriorate. Zones where the climate is cold and dry have been prioritized last for the recall. The availability of replacement parts is also affecting the speed of the repairs. Takata has been given until December 2019 to replace all its airbags still in cars. A list of the states in each zone, including a timeframe for ignitor replacement in those zones, can be found here: (*[*http://www.iihs.org/media/cea05d99-4187-42e9-bdc6-2958ce5adfbb/nAVMcw/QAs/Airbags/IIHS\_Advisory\_40.pdf*](http://www.iihs.org/media/cea05d99-4187-42e9-bdc6-2958ce5adfbb/nAVMcw/QAs/Airbags/IIHS_Advisory_40.pdf)*)*
3. **“What are accelerometers?”** *An accelerometer is similar to a speedometer that measures how fast your car is going, only an accelerometer measures how the speed of your car is changing in a given amount of time. Acceleration can be measured two ways: it can be measured by clocking the change in speed and dividing by the amount of time that speed change took; or it can be measured by using the laws of physics, where*

*force = mass x acceleration.*

*If you know the force and the mass involved, acceleration can be calculated as*

*acceleration = force / mass.*

*In most accelerometers, this is the mathematics that is used to measure acceleration. When you are in an airplane that is taking off you, feel like you are being pressed into your seat. This force is caused by the plane pushing you forward while you are stationary. You might also experience these forces when you are in a car or an elevator. Accelerometer microchips in airbags are designed internally with a small gap between electrodes. When the force acting on the electrodes reduces the distance between the electrodes greater than a predetermined set point, an electrical signal is generated that activates the airbags. Accelerometers in cellphones and handheld gamepads use gravitational force and are programmed to detect the movement of the device in order to reorient the screen. (*[*http://www.explainthatstuff.com/accelerometers.html*](http://www.explainthatstuff.com/accelerometers.html)*)*

1. **“What is sodium azide and what else is it used for?”** *Sodium azide is a fast-acting, potentially deadly, odorless white solid. It reacts with water to form toxic hydrozoic acid which often escapes as a gas upon reaction. Sodium azide is used as a chemical preservative in hospitals and labs, and it is used for pest control in agriculture. If sodium azide is breathed in or absorbed through the skin, it begins acting on the body by preventing the body’s cells from using oxygen. Since the brain and the heart use more oxygen than most other organs of the body, these two organs are affected most by sodium azide poisoning. Survivors of sodium azide poisoning are often left with heart and brain damage. (*[*https://emergency.cdc.gov/agent/sodiumazide/basics/facts.asp*](https://emergency.cdc.gov/agent/sodiumazide/basics/facts.asp)*)*
2. **“What happens to the sodium azide in cars whose airbags are still intact when they are disposed of?”** *This is a good question that doesn’t have a single answer***.** *The Environmental Protection Agency (EPA) has taken the position to let the individual states decide how they want to handle it. Because of the explosive nature of the material in airbags, they are classified as hazardous waste in some states and should be disposed of as a hazardous material. This can be expensive for the car dealer, who must bear some of the cost and maintain responsibility for the material, even after it is disposed of in a designated landfill. It used to be that the intact airbags were either removed from the cars before they were salvaged and then sold as replacement airbags, or they were detonated before the cars were shredded. Depending on the state, this may still be the policy. Sometimes a car would be pressed and shredded with the airbag intact, which caused the release of sodium azide into the environment. Recently, recycling is becoming a preferred way to handle old airbags. There are now companies that will reclaim the parts from airbags, as 95% of the airbag can be safely reused. (*[*https://www.hazardouswasteexperts.com/airbag-hazardous-waste/*](https://www.hazardouswasteexperts.com/airbag-hazardous-waste/)*), (*[*https://earth911.com/general/can-you-recycle-car-airbags/*](https://earth911.com/general/can-you-recycle-car-airbags/)*)*
3. **“Why is moist ammonium nitrate more reactive than the solid form?”** *Ammonium nitrate readily absorbs moisture, which makes the ammonium nitrate pellets, or prills, melt and stick together. The ammonium nitrate cakes, and its configuration in the airbag canister changes. This change in phase and volume also changes the reaction rate and explosive nature of the material. The caked ammonium nitrate becomes explosive rather than being a controlled, fast, gas-producing reaction.**One of the ways that Takata is fixing its defective airbags is to simply add a desiccant to the ammonium nitrate to keep it dry.*
4. **“How does a change in temperature cause the crystal structure of ammonium nitrate to shift?”** *All materials change phase at various temperatures specific to the material. Solid materials can also be affected by thermal expansion. You may have seen a demonstration of this in a previous science class, where the instructor showed a metal ball on a stick that would easily fit through a metal ring on another stick. After placing the ball in a flame, it expanded and would no longer fit through the ring. During phase transitions the volume of the material changes. As the molecules within respond to these temperature changes, their alignment shifts.**The following is an excerpt from a patent application for a new material for the gas generator in airbags. The material was a mixture of nitroguanidine and phase-stabilized ammonium nitrate.*

A problem with the use of pure ammonium nitrate is that the compound undergoes a series of structural phase transformations over the typical operating range of automobile airbag inflators. In pure AN, structural phase transitions are observed at -18° C., 32.3° C., 84.2° C. and 125.2° C. The phase transition at 32.3° C. is particularly problematic during temperature cycling because of a large change in the associated volume, on the order of 3.7% by volume. Generally, any volumetric change is detrimental and it is desired to limit any volumetric change as much as possible.

(<https://patents.google.com/patent/US5545272A/en?q=Stabilized&q=ammonium+nitrate&q=airbags&oq=Stabilized+ammonium+nitrate+for+airbags>)

1. **“What is tetrazole and what else is it used for?”** *Tetrazole is a synthetic cyclic structured compound, composed of a ring of one carbon atom and four nitrogen atoms. Tetrazole derivatives are used in the pharmaceutical industry both as drugs and in biochemical assays, like tests of cell respiration and DNA assays. Tetrazole itself and   
   5-aminotetrazole are stable and have combustive properties that make them suitable to use as a component of gas generators in automobile airbags. The tetrazole reaction produces non-toxic reaction products such as water and nitrogen. (*<https://en.wikipedia.org/wiki/Tetrazole>)

# Activities

**Labs and demos**

**Demonstration of the thermal decomposition of nitrates:** Write a message on absorbent paper with a solution of sodium nitrate. When the paper is dry, hold a glowing splint where the message begins and the message will burn, but the paper will not. (<http://www.rsc.org/learn-chemistry/resource/res00000712/the-thermal-decomposition-of-nitrates-writing-with-fire>)

**“It’s a Crash Test, Dummy Student Lab”:** In this two-part lab, students determine how much sodium bicarbonate to use to inflate a zip-lock baggie and, in the second part, they use their “inflated airbags” to conduct an egg-drop experiment, measuring the height at which they dropped the egg’s container. (<http://sciencenetlinks.com/student-teacher-sheets/its-crash-test-dummy-student-lab/>) The teacher support materials for this lab are found here: http://sciencenetlinks.com/lessons/its-a-crash-test-dummy/.

**Simulations**

**Kinetic theory of gases applet:** This applet gives students a visual experience at the molecular level of how gases behave at different temperature settings. The student can observe the movement of up to three gases while varying the temperature and the number of molecules displayed. (<http://www.falstad.com/gas/>)

**Media**

**”Airbag Design” video (3:04):** The video gives a brief history of airbags and shows clips of early trials while the airbag was being developed. It could be shown as an introduction to the Rohrig article. (<https://www.pbslearningmedia.org/resource/eng06.sci.engin.systems.airbag/air-bag-design/#.WnNM2ojwbDc>)

**“The Alkali Metals: 13 Compounds of Sodium and Nitrogen-Sodium Azide” video (4:28):** From the Royal Society of Chemistry’s *Learn Chemistry* Web page, this clip is taken from Professor Wothers’ lecture series on the alkali metals. In it, the professor discusses the chemistry of the sodium azide decomposition reaction, followed by a demonstration of a car airbag exploding. (<http://www.rsc.org/learn-chemistry/resource/res00001249/the-alkali-metals-part-2>)

A clip of just the demonstration of the car airbag can be found here: <http://www.rsc.org/learn-chemistry/resource/res00001247/its-a-gas-part-3#!cmpid=CMP00002435>.

**Lessons and lesson plans**

**“Creating an Effective Airbag”:** This lesson, which includes applicable teaching standards, uses the scenario of creating an airbag to explore the difference between a strong acid and a weak acid. Students are provided with hydrochloric and acetic acids to react with baking soda, in order to see which one reacts faster to inflate an airbag. The lesson includes the applicable teaching standards. (<https://teacherknowledge.wikispaces.com/Anthony+Thomas+-+Creating+An+Effective+Airbag>)

**“The Chemistry of Airbags”:** In this two-part lesson, students first read about airbags and answer questions from the provided text; while in the second part of the lesson, students design an airbag based on the sodium bicarbonate reaction with acetic acid. Two lesson extensions address the environmental and social issues concerning airbags. (<http://umanitoba.ca/outreach/crystal/resources%20for%20teachers/The%20Chemistry%20of%20Airbags%20C11-2-09.doc>; The *Scientific American* article referenced in the student material can be found here: <https://www.scientificamerican.com/article/how-do-air-bags-work/>.

**Engineering and testing an airbag:** Students calculate the amount and cost of the sodium bicarbonate needed for the reaction with acetic acid to create an airbag that doesn’t burst yet will protect an egg in a drop test. While two of the links within the lesson plans are no longer active, the material contained in the pdf is more than adequate to conduct these well-designed and annotated lessons. (<http://studylib.net/doc/7631587/air-bags--lesson-plan->)

**Projects and extension activities**

**“Save the Drama: Wear a Seat Belt”:** While a seat belt increases the effectiveness of an airbag, statistically teens are the age group with the lowest rate of seat belt use. This *Youth Traffic Safety Month Lesson Plan* makes students aware of this statistic as they work in cooperative learning groups to prepare a skit and prepare discussion questions about four different seat belt-use scenarios. ([http://fcclainc.org/pdf/seat belt.pdf](http://fcclainc.org/pdf/seatbelt.pdf))

Information that complements this lesson plan can be found here: <https://www.cdc.gov/motorvehiclesafety/teen_drivers/teendrivers_factsheet.html>.

**“Air Bags R Us”:** Students are challenged to design airbags for baby carriages. The lesson gives background information on stoichiometry and comes with well-written instructions for this inquiry activity. ([www.iasd.cc/cms/lib07/pa01916506/centricity/domain/371/airbaglab.doc](http://www.iasd.cc/cms/lib07/pa01916506/centricity/domain/371/airbaglab.doc))

# References

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

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



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

Available Now!

In “Airbags—Chemical Reaction Saves Lives”, author Marsella describes the sodium azide reaction used in airbags in 1997. She includes several equations for the multi-step process, from the initial reaction to the final conversion to inert glassy products. (Marsella. G. Airbags—Chemical Reaction Saves Lives. *ChemMatters.* 1997, *15* (1), pp 4–5)

The Teachers Guide for the February 1997 *ChemMatters* article above contains additional information about the physics related to impulse (force x time) in designing airbags. The guide discusses the differences in the force exerted on the head when it hits the steering wheel versus hitting an airbag.

# Web Sites for Additional Information

**History of airbags**

Extensive information about airbags is located in the *Airbag Wiki*. Besides the history of airbag use, statistics about deaths caused by airbags are also reported. (<https://en.wikipedia.org/wiki/Airbag>)

Besides explaining how an airbag works and the physics behind it, this article also has a section on the history of the airbag—complete with the initial drawings from John Hetrick’s 1953 patent application. The article contains helpful links to even more explanation about various parts of the airbag, like accelerometers. (<http://www.explainthatstuff.com/airbags.html>)

**Chemistry of airbags**

“Gas Laws Save Lives: The Chemistry Behind Airbags—Stoichiometry and the Gas Constant Experiment “is a college tutorial containing extensive information about the chemistry and physics used in an airbag. The tutorial uses the sodium azide reaction and provides good information for a teacher or upper-level chemistry students during a unit on gas laws and gas stoichiometry. (<http://www.chemistry.wustl.edu/~edudev/LabTutorials/Airbags/airbags.html>)

This cartoon-illustrated tutorial on chemical reactions contains information about chemical equations, synthesis reactions, decomposition reactions, displacement reactions, and combustion reactions. The section on decomposition reactions uses the airbag reaction as an example. (<https://www.shmoop.com/chemical-reactions/>)

**Takata airbag recall**

An Advisory Notice from the Insurance Institute for Highway Safety (IIHS) contains information specific to the Takata airbag recall. The “Recall Strategy” section identifies how the states were prioritized for the recall. (<http://www.iihs.org/media/cea05d99-4187-42e9-bdc6-2958ce5adfbb/nAVMcw/QAs/Airbags/IIHS_Advisory_40.pdf>)

The article “The True Lesson of an Airbag Disaster” provides an analytical view of the Takata airbag failure and the lessons that can be learned from it in shaping the success of any business. It is a thoughtful article that would make it fun for students to discuss the merits of success and failure and how both contribute to the health of a company. (<https://www.strategy-business.com/blog/The-True-Lesson-of-an-Airbag-Disaster?gko=bcbc1>)

A January 2018 news report and video (0:31) on the Takata airbag disaster and the additional number of cars that are being recalled can be found here: <https://www.cbsnews.com/news/takata-air-bags-recall-expands-to-3-3-million-vehicles/>.

**How airbags work**

“How Airbags Work” explains the science behind airbags, how they work, what their problems are, and recent innovations in airbag technology. The explanations are nicely illustrated. (<https://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/airbag.htm>)

This *Popular Science* article, “How Airbags Work and How They Can Fail”, discusses how airbags accelerometers, as well as other components, work together to protect the driver and passenger. The article discusses the failures of the Takata airbags, supplementing with pictures and video. (<https://www.popsci.com/how-airbags-are-supposed-to-work>)

**How airbags are made**

Great background material and in-depth details on how airbags are manufactured can be found in “Air Bag”, at this *How Products are Made* site: <http://www.madehow.com/Volume-1/Air-Bag.html>.

**Frequent questions about airbags**

This site contains eight questions with answers about how airbags work, the kinds of airbags and recent innovations, the effectiveness of airbags, injuries due to airbags and their prevention, airbags that fail to deploy, and the reuse of airbags from salvaged cars. The site uses videos of crash tests to illustrate the answer to some of the questions. (<http://www.iihs.org/iihs/topics/t/airbags/qanda>)

**Common injuries caused by airbags**

In “Airbags and the Skin”, the author details several types of injuries from airbag deployment commonly seen by doctors. The article includes descriptions of injuries to the eyes and ears as well. (<https://www.medscape.com/viewarticle/490128_1>)

This site on airbag injuries and fatalities examines the cause of several gruesome injuries caused by deploying airbags. It includes forensic evidence, including pictures and x-rays that illustrate the dangers of airbags, and it begins with a brief history of the airbag. (<http://what-when-how.com/forensic-sciences/airbag-related-injuries-and-deaths/>)

**Pitfalls of sodium azide**

This short article, “The deadly poison lurking in your car’s airbags”, describes the health and environmental hazards of sodium azide. (<https://www.naturalnews.com/035643_air_bags_sodium_azide_toxic_chemical.html>)

TheCDC Fact Sheet contains general information about sodium azide. In bullet points, it lists how sodium azide is used, how it works, the signs and symptoms of sodium azide poisoning, and precautions to take for protection from sodium azide exposure. (<https://emergency.cdc.gov/agent/sodiumazide/basics/facts.asp>)

**Infographic or poster**

“The top 5 things you should know about buckling Up” by NHTSA is an infographic on driver and passenger car safety that could be used as a classroom poster. “Airbags are designed to supplement seat belts, not replace them” is the second bullet point in the graphic. (<http://cpsboard.org/cps/wp-content/uploads/2018/01/13331-seat_belt_top_5_flyer_101317_v2_tag.pdf>)

**Interesting information**

You might register a positive breathalyzer test after being in a car where an airbag deployed, due to the Tyndall effect that the powder particles in your lungs have on the testing medium.

(<http://gaduiblog.com/2006/08/07/breath-test-after-airbag-deployment/>)

**Fun video**

“How far can an airbag launch a football?” (6:04) is a short YouTube video of a series of experiments with airbags and a football on a football field. Students will see why they need to make contact with the airbag when it is deflating rather than inflating. (<https://www.youtube.com/watch?v=fgLfhInA6-c>)



**Teacher's Guide for**

### *“The Future of Water/Drinking the Sea”*

**April/May 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Phase changes** | The distillation of seawater to provide freshwater is perhaps a novel way to discuss with students the transitions between the liquid and gaseous phases of water. |
| **Vapor pressure** | When looking at vapor pressure and boiling point, the process of multi-stage flash distillation (MSFD) can add to the discussion. |
| **Boiling** | Multi-stage flash (MSF) distillation of seawater can be used as an example of how boiling can be controlled by changing the pressure on a liquid. |
| **Boiling point** | Desalination techniques provide the opportunity to discuss the normal boiling point of a pure substance, conditions when boiling occurs at a different temperature, and what happens to the boiling point of solutions. |
| **Boiling point elevation** | The energy expense of simple seawater distillation provides an example of problems that can arise due to the boiling point elevation of solutions as distillate is removed. |
| **Separation techniques** | When studying separation techniques involving solutions, the examples of distillation and reverse osmosis to desalinate seawater can show students practical, large-scale, real-world applications. |
| **Distillation** | When introducing separation techniques, your students may think of distillation as one of the most familiar ways to separate liquids. However, they have not considered it a method that has long been used for desalination. |
| **Ions** | This article provides a relevant example of the importance of ions in everyday life, as they must be added back to water that has been desalinated by reverse osmosis, to replenish those lost in the purification process. |
| **Molecular motion** | Both diffusion and osmosis from the article can be used to show molecular motion occurring naturally; while reverse osmosis, a human-controlled process, can be used to show molecular motion that runs counter to that of nature. |
| **Diffusion** | The explanations and examples given in the article can be used to help students use molecular motion to distinguish between diffusion and osmosis. |
| **Chemical engineering (STEM)** | The process of developing ways to apply chemistry to the conversion of seawater into potable drinking water provides an example of the practice of chemical engineering. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5**: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, 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 April/May 2018 issue:

Food Chemistry

Structural Formulas

Chemical Reactions

Reaction Rates

Oxidation & Reduction

Distillation

Environmental chemistry

* Some of the articles in this issue provide information to help students consider their impact on the environment.
* Consider asking students to read “Open for Discussion: Weighing in on calories” to learn about calories in food prior to reading the article “The Protein Myth: Getting the Right Balance.”
* Students may find the infographic on page 19, “As a Matter of Fact: The Aroma of the Seaside” interesting after reading the article “Toxic Shorelines: The Science of Algal Blooms.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their choices regarding food or water use. Also, ask them if they have questions about some of the issues discussed in the articles.

# Reading Supports for Students

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

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

* **Anticipation Guide (p. 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.

***NEW!!!***

Instead of using the Anticipation Guide, consider these ideas to engage your students in reading.

**The Future of Water**

* Before reading, ask students to list at least 3 ideas they have for solving current water crises, including having enough clean water.
* As they read the two articles, ask students to add to the list they have already created.
* **Graphic Organizer (p. 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 (p. 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 Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

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

## Anticipation Guide

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

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. More than 2 billion people around the world live with insufficient clean water. |
|  |  | 1. About 10% of the water on Earth is available as freshwater. |
|  |  | 1. Most of Earth’s freshwater is trapped in glaciers and ice caps. |
|  |  | 1. Distillation of water was discovered in the 1800s. |
|  |  | 1. As salt water is distilled, salt becomes increasingly concentrated in the solution being boiled. |
|  |  | 1. Reverse osmosis requires high pressure to separate fresh water from saltwater. |
|  |  | 1. Desalination currently produces about 10% of the world’s drinking water. |
|  |  | 1. More than16 desalination plants have been approved in California. |
|  |  | 1. Solid water is more dense than liquid water. |
|  |  | 1. Middle Eastern countries have proposed towing icebergs to drought-stricken areas. |

## Graphic Organizer

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

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

**Directions**: ***As you read***, complete the graphic organizer below to compare different methods of desalination.

|  |  |  |
| --- | --- | --- |
|  | ***Distillation*** | ***Reverse Osmosis*** |
| What is it? |  |  |
| Where is it used? |  |  |
| What are some drawbacks? |  |  |
| How might it be used in the future? |  |  |

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

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

## Student Reading Comprehension Questions

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

Name

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

**from “The Future of Water”**

* 1. (a) Where is groundwater located, and (b) what is one way to access it?
  2. (a) What percentage of the water on earth is freshwater? (b) Calculate the percentage of this water that is not immediately available because it is either in the ground or frozen in glaciers and polar ice caps?

**from “Drinking the Sea”**

* 1. Describe, on the molecular level, the process of distillation.
  2. Why does distilling saltwater to provide freshwater for a community become very energy intensive?
  3. Explain the process that scientists and engineers use to reduce the amount of energy lost during distillation of seawater.
  4. Explain the process of osmosis.

1. **Student Reading Comprehension Questions, cont.**

“The Future of Water/Drinking the Sea”, *ChemMatters*, April/May 2018

1. How does reverse osmosis work to desalinate saltwater?
2. In the desalination process, what is the purpose of (a) pre-treatment and (b) reverse osmosis?
3. During the process of desalination, why is water poured over rock beds?
4. (a) Which type of desalination process (distillation or reverse osmosis) uses the least amount of energy? (b) Why does its use still present a problem?
5. According to environmentalists, what is a major concern about desalination plants?
6. Give two reasons why the need for desalination will probably continue to increase.

## Answers to Student Reading Comprehension Questions

**from “The Future of Water”**

1. **(a) Where is groundwater located, and (b) what is one way to access it?**

*Groundwater is freshwater located below the surface of the ground.*

*One way that it can be accessed is by pumping it from wells.*

1. **(a) What percentage of the water on earth is freshwater? (b) Calculate the percentage of this water that is not immediately available because it is either in the ground or frozen in glaciers and polar ice caps?**
2. *2.8% of the water on earth is freshwater.*
3. *30% Groundwater OR 100% Total freshwater*

*+ 69% Frozen water – 1% Surface freshwater*

*99% Total freshwater not 99% Total freshwater not*

*readily available readily available*

**from “Drinking the Sea”**

1. **Describe, on the molecular level, the process of distillation.**

*As seawater is heated, the water molecules move faster and faster until they eventually reach their boiling point (100 oC), where they vaporize and can then be collected as distillate (pure water) leaving behind the higher boiling point salt.*

1. **Why does distilling saltwater to provide freshwater for a community become very energy intensive?**

*As the water evaporates, the solution of salt and water left in the boiling container becomes increasingly concentrated, causing the boiling point of the solution to increase and requiring more energy to vaporize water from that more concentrated solution.*

1. **Explain the process that scientists and engineers use to reduce the amount of energy lost during distillation of seawater.**

*Scientist and engineers reduce the amount of energy lost during the distillation of seawater by using multi-stage flash distillation (MSFD). During MSFD seawater is heated in stages, using the heat from the hot water remaining in the container to initially heat the cool, starting seawater.*

1. **Explain the process of osmosis.**

*Osmosis occurs when a semipermeable membrane separates two salt solutions of different concentrations. Assuming this membrane allows only the passage of water molecules to reach equilibrium concentration, the water molecules will move from where the relative amount of salt is low to where the relative amount is high.*

1. **How does reverse osmosis work to desalinate saltwater?**

*In reverse osmosis, high pressure is applied to a salty solution in contact with a semipermeable membrane. To relieve the pressure, the water molecules move from the concentrated solution side through the semipermeable membrane, to be collected as fresh water on the other side of the membrane.*

1. **In the desalination process, what is the purpose of (a) pre-treatment, and (b) reverse osmosis?**

*In the desalination process,*

1. *pre-treatment is used to remove large components, such as algae, from the seawater, and*
2. *reverse osmosis is used to remove the salt from seawater.*
3. **During the process of desalination, why is water poured over rock beds?**

*Water is poured over rock beds during the process of desalination to dissolve low concentrations of rock minerals into the water.*

1. **(a) Which type of desalination process (distillation or reverse osmosis) uses the least amount of energy? (b) Why does its use still present a problem?**
2. *The reverse osmosis process uses less energy than distillation, but*
3. *it still presents a problem because the start-up costs for new facilities are high.*
4. **According to environmentalists, what is a major concern about desalination plants?**

*A major environmental concern about desalination plants is that they steadily release the unnaturally salty water (left over after much of the freshwater has been removed) to the ocean, and this briny solution could harm marine ecosystems.*

1. **Give two reasons why the need for desalination will probably continue to increase.**

*The need for desalination will probably continue to increase*

1. *as populations grow and*
2. *climate change affects rainfall patterns.*

*Both of these changes increase the need for freshwater.*

# Possible Student Misconceptions

1. **“I am concerned because the energy for desalination comes from the burning of fossil fuel and this leads to global warming.”** *Fortunately, this is not always true. China’s desalination plants are powered by the wind; Saudi Arabia uses solar power; and Australia is using the energy from ocean waves—as they pass over submerged buoys tethered to pumps on the ocean floor, the motion of the waves drives the pumps.*
2. **“Desalination is so expensive that I don’t think the urgency for more water is a strong concern in the U.S.”** *Actually, there is considerable concern in the Western U.S. California has been pumping so much groundwater to meet their needs for human consumption and agriculture that the land is beginning to sink. In addition, the largest western U.S. water storage area, Lake Mead on the Colorado River, is now at only 39% of its capacity.*
3. **“I heard that water from reverse osmosis is bad for you because the process removes all essential minerals such as calcium and magnesium.”** *Although the reverse osmosis process does remove all ions from the water, essential mineral ions like calcium and magnesium are added to the desalinated water before it is sent to consumers.*

# Anticipating Student Questions

1. **“Why does distilled or demineralized water taste so ‘flat’”?** *Water without ions (minerals) lacks flavor, so water companies usually add minerals to water before it is sold to consumers. You probably use demineralized water in the chemistry lab to prevent interaction between the ions in your experiment and ions present in the water.*
2. **“What will happen if you drink seawater when you are desperately thirsty?”** *This is not a good idea.**You might get sudden severe diarrhea, urinate frequently, and become extremely thirsty—all because your kidneys need fresh water to dilute and expel the seawater, a very concentrated salt solution. If you continue to drink seawater, dehydration may lead to death. By osmosis, water molecules move through the cell membrane, leaving your body cells, where the* ***water*** *concentration is high, to dilute the seawater (low water concentration) that you drank.*
3. **“Sometimes we use distilled water in our chemistry labs; other times we use deionized (DI) water. What is the difference?”** *Both remove ionic impurities, so they work well for most pre-college experiments. However, their preparation methods differ, so their use in technical labs may differ. Volatile organics and metals like mercury will volatilize along with water during distillation, so the purity of distilled water depends upon the source water. Ions and other charged particles are removed from water as it passes through the electrically-charged resin to form DI water, but this process will not remove uncharged particles like sugar molecules, bacteria, and viruses.*
4. **“What about the people in poor countries with little water and no money to build desalination facilities?”** *In 2015, researchers at Alexandria University developed a cheap, quick method to desalinate saltwater. Membranes to filter out salt and large impurities are made from local materials plus a cellulose acetate powder that binds salt. Once filtered, the individual user at home needs to just heat, vaporize and condense the potable water filtrate.*
5. **“I read that reverse osmosis makes the water acidic. How does this happen?”**

*Following reverse osmosis, the pure water contains essentially no ions, so it is neutral; but, as soon as it’s exposed to atmospheric carbon dioxide, it becomes acidic:*

*H2O (*l*) + CO2 (g) 🡨🡪 H2CO3 (aq) 🡨🡪 2 H+ (aq) + HCO3– (aq)*

*(carbonic acid)*

*The hydrogen ions produced could corrode water pipes, so remineralization is used following reverse osmosis, via filters containing calcium and magnesium compounds, to neutralize the water and also to return essential minerals that were lost during the reverse osmosis process:*

*Ca2+ (aq) + 2 HCO3– (aq) 🡪 CaCO3 (s) + H2O (*l*) + CO2 (g)*

*Mg(OH)2 (s) + 2 H+ (aq) 🡪 Mg2+ (aq) + 2 H2O (*l*)*

*See this link for a further description of f****our solutions that are widely used to remineralize desalinated water. (***[*https://www.lenntech.com/processes/desalination/post-treatment/post-treatments/remineralization.htm*](https://www.lenntech.com/processes/desalination/post-treatment/post-treatments/remineralization.htm)*)*

# Activities

**Labs and demos**

“**Desalination of Sea Water”, laboratory activity:** This clearly written laboratory activity involves distillation, electrolysis, calculations and discussion questions. A diagram of an electrochemical cell and all the relevant redox equations are included. (<https://scilearn.sydney.edu.au/fychemistry/LabManual/E07.pdf>)

**“Water Distribution Demonstration”:** This demonstration—using water, a medicine dropper, and a graduated cylinder—provides a quick, easy way to draw attention to the minuscule amount of Earth’s water that is available freshwater. Complete instructions and suggested student questions are provided. (<http://cmase.pbworks.com/w/file/fetch/65195601/Water%20Distribution%20Demonstration.pdf>)

**Simulation**

**“Water Desalination by Electrodialysis”, a simulation challenge for students:** A simulator asks students to design a desalination process to purify brackish water with 7ppm salinity for the least cost per unit. Students will decide cell dimensions and cell stack, flow pressure level and amount of voltage needed; guidance for use of the simulator and additional challenges are provided. (<http://desalination.stanford.edu/simulation.html>)

**Media**

**“Boiling Point Elevation and Freezing Point Depression”, video (13:59):** This *Khan Academy* video uses diagrams to represent molecules as it explains the elevation of boiling point at the particulate level. It explains the increasing energy requirements as the salt concentration of the remaining solution increases during distillation. (<https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces/mixtures-and-solutions/v/boiling-point-elevation-and-freezing-point-supression>)

**“Making Desalination more Sustainable”, video (4:17):** Both animation and photos from industrial plants are used to describe various techniques to desalinate water; the energy required for each process is included. A new hybrid process developed by universities in Saudi Arabia and Singapore reduces the energy requirements of the other technologies by combining multi-effect desalination with adsorption desalination (MEDAD). (<https://www.youtube.com/watch?v=-ZenuOGTohk>)

**Lessons and lesson plans**

**“Process and Impact of Desalination on the Environment” (3+ days):** In this comprehensive NGSS-based lesson plan (grades 6–12), students study various ways to desalinate water, researching both the economic and environmental costs of these processes, while constructing a small-scale solar cell to desalinate water. This complete lesson plan from *Water Education Today* includes instructions, questions, teacher’s guide, and evaluation rubrics. (<http://watereducationtoday.com/pdf/WET_Lesson_Plan_11_Process_and_Impact_of_Desalination_on_the-Environment.pdf>)

**“Ocean Water Desalination”, NGSS lesson with the focus on engineering (60 min.):** Desalination processes are described as systems; students study nature’s water purification system, followed by engineering designs to desalinate water, which include multi-stage flash distillation, reverse osmosis, and electrodialysis. Students are asked to sketch desalination systems that they design.

(<https://www.teachengineering.org/lessons/view/cub_desal_lesson01>)

**Projects and extension activities**

**“The Global Water Crisis”, suggestions for projects:** This Pulitzer Center program, introduced by videosfrom water-poor countries, provides data and suggests extension projects that include creative writing, debates, and research. The specific lessons focus on the water-poor countries of Ethiopia, Yemen, Kenya, and Nepal. (<http://pulitzercenter.org/education/lesson-plan-global-water-crisis>)

# References

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

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



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

Available Now!

Although this article is dated (2002), the diagram of the reverse osmosis (RO) system is well labeled and described. It includes a demonstration of the amount of potable water in the world and a lab where students test and compare tap water to filtered water. (Stewart, M. Tapping Salt Water for a Thirsty World. *ChemMatters,* 2002, *20* (3), pp 4–9)

This article uses a diagram and electrochemical equations to show an exciting new desalination technique using a bacteria-powered fuel cell to produce electricity as it removes salt from water. To date (as of 2010), this cutting-edge cell is still on the lab bench, not yet ready for a step-up to the industrial scale. (Anderson, L. Putting Bacteria to Work. *ChemMatters,* 2010, *28* (4) pp 14–17)

# Web Sites for Additional Information

**General summaries**

“Tapping the oceans” is an excellent article that describes the technological history of desalination and the worldwide need for water. It also discusses desalination’s high energy demands, scientific advances to reduce these, and the associated concerns of environmental pollution. (<http://www.economist.com/node/11484059>)

Hanson Cheah, Massachusetts Institute of Technology (MIT) graduate now working as a global entrepreneur based in Hong Kong, has prepared a series of excellent, clear and short descriptions using particle-based schematics of four types of seawater desalination processes, multi-stage flash distillation (MSFD), multi-effect distillation (MED), vapor compression (VC), and membrane processes such as reverse osmosis (RO). These links are all listed under the heading: “Seawater Distillation” on the left column of this Web site. (<http://www.separationprocesses.com/Distillation/MainSet1.htm>)

**History of desalination**

The equipment diagrams provided on this site, with their brief descriptions of processes that have been used over time to desalinate seawater, provide a good overview of the history and technological advances of desalination. Beginning with the evaporation of saltwater on steamships, the article moves through RO and electrodialysis and concludes with multi-stage flash distillation (MSFD). (<http://www.brighthubengineering.com/structural-engineering/109915-multi-stage-flash-distillation-for-desalination/>)

This site describes and pictures the important events in desalination history from 1600 (on steamships) to April 7, 2010 (a solar-powered plant in Saudi Arabia). The reader can scroll across the timeline clicking on any entry for more information, or toggle to the “list”, which provides the details for and a photo of each item on the timeline. (<https://www.timetoast.com/timelines/important-events-in-desalination-history>)

**Sugar refining leads to new desalination processes**

In 1850, U.S. chemical engineer Norbert Rillieux tackled the problem of removing water from sugar cane juice. He developed a technique using multiple-effect vacuum evaporation, the same energy-saving technology used about 50 years later for the multiple-effect distillation (MED) process. (<https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/norbertrillieux.html>)

**Worldwide water shortages**

“Why freshwater shortage will cause the next global crisis” predicts that fresh water shortages will be the next worldwide crisis; colored global maps show relationships between water stress and climate change. As the climate changes, projections show that both the quantity of freshwater and its purity will decrease. (<https://www.theguardian.com/environment/2015/mar/08/how-water-shortages-lead-food-crises-conflicts>)

“Is the world running out of fresh water?” is a paper from the British Broadcasting Corporation (BBC) that quotes a National Aeronautics and Space Administration-led (NASA) study (link included) on water resources, showing that the world is draining freshwater faster than it is being replenished. The article points to the high cost of desalination to meet global water needs and suggests ways to save water by improving agriculture efficiency and by recycling wastewater. (<http://www.bbc.com/future/story/20170412-is-the-world-running-out-of-fresh-water>)

**Major desalination processes**

IDE technology provides details of desalination by RO and by thermal desalination (VC, MED, MSF—links can be found at this URL for further description). This site includes energy requirements, along with details of each process, and labeled photos of plants worldwide, including two in California.

(<http://www.ide-tech.com/desalination/>)

In addition to distillation and RO, a third way to desalinate is particularly useful for recovering pure potable water from highly salted and/or contaminated water coming from fracking facilities and other wastewater sources. The interesting process of shock electrolysis, where electrically charged membranes are used to separate pure water from briny materials, is fully described in this MIT bulletin. (<http://news.mit.edu/2015/shockwave-process-desalination-water-1112>)

**Reduction in energy cost**

The history and high cost of desalination are followed by a focus on reducing the cost of RO membranes and applying nanotechnology techniques to design strong, chemical-resistant, highly-absorbent graphene membranes that require less pressure and energy. Additional suggestions include reducing energy by the RO-PRO (Pressure retarded osmosis) process, recapturing/recycling energy processes, and, finally, improving efficiency by replacing large industrial complexes with small community facilities. (<https://www.pri.org/stories/2015-05-15/desalination-expensive-energy-hog-improvements-are-way>)

Descriptions and diagrams of current technologies including electrodialysis, RO and solar distillation (SD); costs for various desalination processes are given, alternative energy sources are discussed and an excellent “At a Glance” table summarizes this information. The method chosen usually depends upon the resources of the country; the oil-rich can afford fuel energy-intensive technologies and arid equatorial coastal countries can use SD. (<https://www.sswm.info/content/desalination>)

**Post-treatment of desalinated water**

Although some Web sites declare the horror of desalinated water killing 100s of people, the World Health Organization (WHO) has produced safety guidelines to dispel the fear: “Safe Drinking-Water from Desalination”. Whatever method is used, post-treatment is essential to avoid blending the pure distillate with untreated, contaminated source-water, and to add minerals to supplement the primary dietary sources of these ions. (<http://apps.who.int/iris/bitstream/10665/70621/1/WHO_HSE_WSH_11.03_eng.pdf>)

The Israeli government is addressing four important steps described in the URL below to reduce public risk from contaminated water. Due to the lack of appropriate desalination post-treatment, citizens have experienced “red” water, when a high percentage of desalinated water lacking required buffering capacity was incorporated into their water supply; in addition, the lack of magnesium has led to decreased lung function in children and increased heart attacks in older people. (<https://www.haaretz.com/science-and-health/israel-dawdling-as-desalinated-water-kills-1.5462030>)

**Environmental impact of desalination**

This article focuses on both the economic and the environmental impacts of desalination; desalination produces very expensive water, and it contributes to climate change and global warming when the energy source is fossil fuel. The article also discusses issues of threats to ocean biodiversity, marine habitats, and coral reefs. (<http://www.theenergycollective.com/bobbipeterson/2396669/desalination-and-energy-consumption>)

“The Future of Seawater Desalination: Energy, Technology, and the Environment,” published in *Science,* includes suggestions for mitigating the impact of briny water discharge (twice the salinity of natural seawater) from desalination plants. Solutions include: placing desalination plants away from sensitive areas like coral reefs; considering a position near a power plant or waste-treatment plant that would mix and dilute the brine with treated fresh water; and developing foul-resistant membranes.

(<https://albertsk.files.wordpress.com/2012/08/science-2011-elimelech-712-71.pdf>)



**Teacher's Guide for**

### *“Towing Icebergs”*

**April/May 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Density** | Planning to tow an iceberg is not an easy process, due to its huge mass below the ocean’s surface; the amount below the surface can be predicted by comparing the density of ice with the density of seawater. |
| **Buoyancy** | The Titanic disaster might have resulted at least partially because engineers onboard the ship were unaware that, although barely visible, a huge piece of the iceberg (approximately 90%) was situated below the ocean surface. This tragic example can be used to illustrate the importance of understanding Archimedes’ principle of buoyancy. |
| **Phase changes** | Although ocean water is usually considered very cold, it is still warmer than ice, as explained in the article. The temperature difference between ice and the ocean water through which they travel is sufficient to cause a phase change from solid ice to liquid water, melting the iceberg. |
| **Melting** | The loss of significant amounts of water from an iceberg that would occur if it were towed in the long journey over open water, from icy areas to the hot, water-scarce United Arab Emirates, provides an example of the process of melting. |
| **Heat exchange** | This article provides an example of a real-world problem due to heat exchange. During iceberg towing, when heat flows from the warmer ocean water (15–20 oC) to the colder iceberg (<0 oC), the heat energy melts the ice. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5**: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, 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 April/May 2018 issue:

Food Chemistry

Structural Formulas

Chemical Reactions

Reaction Rates

Oxidation & Reduction

Distillation

Environmental chemistry

* Some of the articles in this issue provide information to help students consider their impact on the environment.
* Consider asking students to read “Open for Discussion: Weighing in on calories” to learn about calories in food prior to reading the article “The Protein Myth: Getting the Right Balance.”
* Students may find the infographic on page 19, “As a Matter of Fact: The Aroma of the Seaside” interesting after reading the article “Toxic Shorelines: The Science of Algal Blooms.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their choices regarding food or water use. Also, ask them if they have questions about some of the issues discussed in the articles.

# Reading Supports for Students

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

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

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

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

* **Student Reading Comprehension Questions (p. 10-11):** 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 Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“Towing Icebergs”, *ChemMatters*, April/May 2018

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

## Anticipation Guide

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

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. More than 2 billion people around the world live with insufficient clean water. |
|  |  | 1. About 10% of the water on Earth is available as freshwater. |
|  |  | 1. Most of Earth’s freshwater is trapped in glaciers and ice caps. |
|  |  | 1. Distillation of water was discovered in the 1800s. |
|  |  | 1. As salt water is distilled, salt becomes increasingly concentrated in the solution being boiled. |
|  |  | 1. Reverse osmosis requires high pressure to separate fresh water from saltwater. |
|  |  | 1. Desalination currently produces about 10% of the world’s drinking water. |
|  |  | 1. More than16 desalination plants have been approved in California. |
|  |  | 1. Solid water is more dense than liquid water. |
|  |  | 1. Middle Eastern countries have proposed towing icebergs to drought-stricken areas. |

## Graphic Organizer

“Towing Icebergs”, *ChemMatters*, April/May 2018

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

**Directions**: ***As you read***, complete the graphic organizer below to describe ideas that have been put forward to tow icebergs to areas needing fresh water.

|  |  |  |
| --- | --- | --- |
| 3 | **People who proposed towing icebergs, and when** |  |
| 2 | **Problems with towing icebergs** |  |
| 1 | **Number or statistic from the article that surprised you (and why)** |  |
| Contact! | **What do *you* think about the idea of towing icebergs to drought-stricken areas?** |  |

## Student Reading Comprehension Questions

“Towing Icebergs”, *ChemMatters*, April/May 2018

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

Name

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

1. What event prompted the interest in towing icebergs to prevent disasters at sea?
2. What stimulated the idea of towing icebergs to California?
3. List two possible problems with the Saudi Arabian prince’s plan in 1977 to supply fresh water to his country.
4. When estimating the cost of towing an iceberg, why is it important to consider the wind and ocean current flows in the cost analysis?
5. In addition to considering the wind and ocean current flows, give two other variables to consider when computing the estimated cost of towing an iceberg from Newfoundland to the Canary Islands.

**Student Reading Comprehension Questions, cont.**

“Towing Icebergs”, *ChemMatters*, April/May 2018

1. Why is melting considered a serious problem during the iceberg towing?
2. What has been suggested as a solution to the problem of iceberg melting during towing?
3. How did researchers determine that towing the iceberg from near Newfoundland to the Canary Islands would be physically possible?
4. According to Georges Mougin’s simulation, (a) how long would the journey take, and (b) how much ice would melt?
5. Since the Mougin plan was never carried out, has everyone given up on towing icebergs? Explain your answer.

## Answers to Student Reading Comprehension Questions

1. **What event prompted the interest in towing icebergs to prevent disasters at sea?**

*The sinking of the Titanic prompted the interest in towing icebergs, to prevent future disasters at sea.*

1. **What stimulated the idea of towing icebergs to California?**

*The idea of towing icebergs to California was stimulated by the need for freshwater in southern California.*

1. **List two possible problems with the Saudi Arabian prince’s plan in 1977 to supply fresh water to his country.**

*To reach Saudi Arabia,*

1. *the iceberg would have to be towed across 11,500 kilometers of water, and*
2. *if it weighed 100 million tons, the estimated cost to do this would be $100 million.*
3. **When estimating the cost of towing an iceberg, why is it important to consider the wind and ocean current flows in the cost analysis?**

*It is important to consider the wind and ocean current flows in the cost analysis when estimating the cost of towing an iceberg because the wind and ocean current flows may either help or hinder the movement of the iceberg through the sea.*

1. **In addition to considering the wind and ocean current flows, give two other variables to consider when computing the estimated cost of towing an iceberg from Newfoundland to the Canary Islands.**

*Two other variables to consider when computing the cost of towing an iceberg from Newfoundland to the Canary Islands are*

1. *the size of the iceberg, and*
2. *the number and power of the tugboats.*
3. **Why is melting considered a serious problem during the iceberg towing?**

*Melting is considered a serious problem during iceberg towing because if an iceberg at 0 oC is towed through the seawater that has a higher temperature (and at 15 to 20 oC, it is warmer), heat would flow from the warmer seawater and melt the ice en route.*

1. **What has been suggested as a solution to the problem of iceberg melting during towing?**

*A suggested solution to the problem of iceberg melting during towing is to develop a way to wrap a skirt around the iceberg to trap the freshwater as it melts.*

1. **How did researchers determine that towing the iceberg from near Newfoundland to the Canary Islands would be physically possible?**

*Researchers used a computer simulation to determine that it is physically possible to tow an iceberg from near Newfoundland to the Canary Islands (although not financially reasonable).*

1. **According to Georges Mougin’s simulation, (a) how long would the journey take, and (b) how much ice would melt?**

*According to this Mougin’s simulation,*

1. *the journey would take 141 days, and*
2. *approximately 38% of the iceberg would melt.*
3. **Since the Mougin simulation was never carried out, has everyone given up on towing icebergs? Explain your answer.**

*No, everyone has not given up on towing icebergs. In 2017, the United Arab Emirates, countries with plenty of oil but very little water, introduced another plan.*

# Possible Student Misconceptions

1. **“Icebergs are always found in the ocean, so they must be frozen sea water that will have to be desalinated before drinking.”** *Actually, icebergs are formed on land, they are freshwater pieces of glaciers or ice caps that break off, or* calve*, and float in the ocean.*
2. **“I’ve seen the advertisements for towing icebergs that picture the penguins and polar bears still on the huge iceberg.”** *First, iceberg tugs do not bring animals on the icebergs and, second, penguins inhabit the Antarctic, but polar bears live only in Arctic regions.*
3. **“Since icebergs are frozen, they cannot support life.”** *The glaciers that formed icebergs were covered by dirt, microbes, and other airborne debris, along with snow. As the snow melted, its water mixed with biological material, and colonies of bacteria formed. This “living surface” was part of the iceberg that formed when the glacier broke (“calved”) into the ocean.*
4. **“Polluted icy seawater must contaminate icebergs.”** *The deep layers of the iceberg have formed from years of heavy pressure, making them impermeable to seawater. Even when the sea freezes, only the pure freshwater forms sea ice; the salt and other contamination does not freeze, nor can it contaminate icebergs.*
5. **“I hear a lot about the sea-water level rising due to global warming; this must be caused by icebergs melting.”** *No, icebergs are already floating in the ocean, so the sea level doesn’t change as they melt. Sea-level rise occurs when glaciers and ice caps on land melt, and that water flows into the ocean, increasing the ocean volume and flooding low land areas.*

# Anticipating Student Questions

1. **“Why is it important that oceans freeze from the top to the bottom?** *Thick ice on the top of seawater allows people and animals to travel across the ice and marine life to survive under the ice.*
2. **“How much of an iceberg is located beneath the surface?”** *Approximately 90% of the iceberg is located underwater. Ice floats in liquid water because the ice is less dense than the liquid water that it displaces. Ice has a density of .917g/mL compared to 1.03g/mL, the density of seawater:*

*917g/mL ice / 1.03g/mL seawater x 100% = 89.0%*

*Thus, approximately 90% of the iceberg will remain underwater because it is not supported by the buoyant force of water.*

1. **“I’ve heard of glaciers *calving*. What causes this?”** *Glaciers are huge masses of dense ice that move slowly under their own weight (like rivers of ice). Their forward motion to the sea makes the forward end of the glacier unstable, so the ice breaks (calves) into the ocean, forming icebergs.*
2. **“Why does an iceberg made of freshwater appear white instead of clear?”** *Tiny air bubbles trapped in layers of snow on top of the iceberg reflect sunlight so the iceberg looks white (just like snow).*
3. **“I’ve seen photos of blue icebergs, how is this possible?”** *After the snow on top of an iceberg melts, the internal compressed layers of glacial ice are exposed. These layers lack a reflective surface, allowing long red wavelengths to penetrate and be absorbed by this ice; thus, light is transmitted through the ice as blue or blue-green.*

# Activities

**Labs and demos**

**“How much of an iceberg floats above the surface”, ~~a~~ hands-on activity (20 min.):** Students float a frozen piece of freshwater in salt water, measure, and calculate the percentage of the “iceberg” above water. The teachers’ guide includes a list of lab materials and directions, NGSS alignment, discussion questions, and an extension idea. (<https://www.cresis.ku.edu/sites/default/files/Education/K-12/IceIceBaby/4.1-IIB_lesson.pdf>)

**“Sea Level Change Experiment”, student investigation:** To dispel a common misconception**,** students investigate the effect of global warming on sea-level rise by constructing an island with a glacier, surrounded by a sea with icebergs. They measure the sea level rise as a glacier melts, compared to the effect when an iceberg melts. (<http://www.dynamicearth.co.uk/media/1238/sea-level-change-experiment.pdf>)

**Media**

**“How are icebergs formed”, terrific video (4:10):** As excellent narration explains this process, the viewer is taken from the probable birth of an iceberg to its death. A description of an iceberg near the end of its life cycle suggests the probable behavior of the one that destroyed the Titanic. (<https://www.youtube.com/watch?v=LCeIiNEhUWk>)

**“Have you ever harvested an iceberg?”, video (6:06):** Hunters capture chunks to melt and sell as “Iceberg Water”, deemed fresh, clean, and ready to bottle for sale. In Newfoundland, hunters must be licensed to catch iceberg chunks, and the use of explosives to break icebergs into smaller pieces, as shown in the film, is prohibited. [Note: other sources say this iceberg-melt must be tested for possible iceberg surface pollution/contamination.] (<https://www.youtube.com/watch?v=07imCx95vXg>)

**Lessons and lesson plans**

**“Do-it-yourself iceberg science”, film canisters with frozen water act as icebergs:** This scientific inquiry lesson includes the study of density and phase changes to explain the position and movement of icebergs. The lesson is referenced to NGSS standards, with extensions that include experimental design. (<https://www.units.miamioh.edu/cryolab/education/documents/MS%20Icebergs.pdf>)

**“Witnessing Icebergs” (60:00), high school environmental class, NGSS-aligned lesson:** Students study how glaciers affect global stability by considering how melting changes sea levels, weather, and marine environments. Readings and internet resources form the basis for discussion questions and reflective prompts. (<https://www.globalonenessproject.org/resources/lesson-plans/witnessing-icebergs>)

**Projects and extension activities**

**“Activity Guide: Titanic Science”, history and hands-on activities woven into the story of the Titanic:** This K-12 “Teachers’ Guide” can be used as an excellent, very complete unit of study that contains many activities, including buoyancy, designing a ship, making an iceberg, plotting icebergs, and calculating their frequency. A matrix displays connections to the National Standards and suggested videos are from the Discovery Channel. (<http://www.theteachersguide.com/sciencemisc/titanicscienceteachersguide.pdf>)

# References

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

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



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

Available Now!

This article includes the history of the Titanic and a clearly-illustrated description of buoyant force. The author describes various modern hypotheses to explain the sinking and loss of life on the “unsinkable” Titanic, including the brittleness of the steel hull, hitting the iceberg from the side rather than from the stronger front of the ship, insufficient life rafts, and the lack of modern warning systems. (Rohrig, B. Titanic. *ChemMatters*, 2011, *29* (4) pp.17–19)

# Web Sites for Additional Information

**History of towing icebergs**

“The Many Failures and Few Successes of Zany Iceberg Towing Schemes”, a terrific article with many iceberg tales to spice classroom lessons, includes links for additional information. The history of iceberg towing adventures from the 1800s to 2007 describes small Chilean icebergs equipped with sails to add wind power to ships towing them north, and the 1835 British Arctic Expedition ship that was stuck on an iceberg which towed it about the ocean. (<https://www.theatlantic.com/technology/archive/2011/08/the-many-failures-and-few-successes-of-zany-iceberg-towing-schemes/243364/#slide3>)

With tales to add fun to your classroom discussions, this article goes from describing modern day “snake oil salesmen” who peddle bottled glacier water as legitimate businesses, to multi-million dollar scams. A brief history of the “cold rush” and ice-related climate changes are described in both the text and as picture columns on the right side of pages. (<http://www.icebergwatereurope.com/wp-content/uploads/2014/01/ModernFarmer_jan141.pdf>)

**Feasibility studies**

At the 1977 International Iceberg Summit in Iowa, a Saudi Arabian prince submitted a proposal developed by the French scientist Georges Mougin to tow a 100-million-ton iceberg wrapped in a “skirt” to save melted water from the North Pole to Red Sea drought areas at a cost of $100 million. Dismissed by its impracticality and cost, Mougin set the idea aside for 35 years and then tackled the problem in 2011 by simulation using 3-D technology, modern ocean forecasting, and strong tugboats. (<https://www.fastcompany.com/1755444/watch-tugboat-drag-arctic-iceberg-parched-people-half-world-away-video>)

This article details the 2017 United Arab Emirates (UAE) plan to launch the “Emirates Iceberg Project”, with ways to tow icebergs from the Antarctic to the Arabian Peninsula, the least water-secure area in the world. They note that with 80% of the ice under water and a white surface that reflects sunlight, icebergs melt slowly. (<https://fanack.com/icebergs-uae/>)

**Desperate need for water**

Following several years of drought, attributed to global warming and explosive population growth, April 12, 2018, is “Day Zero” for Cape Town, South Africa. This is the day when water taps will run dry—unless drastic conservation and recycling and/or iceberg towing occur immediately. (<http://abcnews.go.com/International/wireStory/cape-town-set-disaster-operations-hq-water-crisis-52664503>)

Proposals for Antarctic iceberg towing as a temporary solution for Cape Town’s water shortage come from (also water-poor) Abu-Dhabi of the United Arab Emirates (UAE). The UAE has long considered iceberg towing as a probably less expensive option than desalination to provide water during extreme drought. This article also suggests the need for a deep harbor in which to float the iceberg and describes the process of freshwater retrieval. (<https://www.dailymaverick.co.za/article/2017-10-16-capewatergate-could-towing-an-iceberg-to-cape-town-help-solve-future-water-problems/#.WnISuHmpVMs>)

**Dangers of towing icebergs**

The International Ice Patrol (IIP), launched following the Titanic disaster to monitor the location of icebergs, now uses data from satellites, radar, and airplanes to locate icebergs in shipping lanes and recommends safe routes around them. The information collected is used by contractors that tow icebergs away from oil rigs in ocean waters, a risky business, as tugs must maintain a safe distance (as seen in the photo) in case the iceberg flips. (<http://www.neatorama.com/2014/05/23/Risky-Business-Towing-Icebergs/>)

In addition to collisions with ships, icebergs can flip over due to melting that leaves them unbalanced, releasing enough energy to cause rough seas, tsunamis, and occasional earthquakes. This article contains a photo of a recently-flipped iceberg’s glassy underwater belly, with no white snow from the original iceberg top visible. (<https://www.smithsonianmag.com/science-nature/photographer-captures-stunning-underside-flipped-iceberg-180953951/>)

**Problems with harvesting icebergs for fresh water**

The article “Can we use icebergs as a source of water?” suggests two problems with towing icebergs: melting, and pulling an iceberg near land; ways to solve them; and easier ways to harvest their water. (<https://www.scienceabc.com/nature/can-we-use-icebergs-as-a-source-of-water.html>)

This *Newsweek* article discusses the problems of towing an iceberg from Antarctica to Dubai. Beyond the expense, melting, and difficult land approaches, there are extremely strong ocean undercurrents in the South Atlantic, as well as multi-nation environmental regulations that span the route. (<http://www.newsweek.com/iceberg-move-expert-climate-change-dubai-uae-south-pole-antarctica-610623>)

**Iceberg harvesting in Newfoundland**

Another *Newsweek* article describes the dangers faced by iceberg hunters as they drag pieces of icebergs that have calved from the Greenland ice shelf and floated to the coast of Newfoundland. Onshore, the chunks are melted, bottled, and sold as expensive, bottled “Iceberg” water. (<http://www.newsweek.com/iceberg-hunters-newfoundland-414728>)

“Iceberg Harvesting: Suggesting a Federal Regulatory Scheme” was published in the *Boston College Environmental Affairs Law Review*, April 2015. This article contains some recent history about the possible plans to tow icebergs to thirst-hungry areas of the world, and it cautions that currently, this activity is in a “legal vacuum” with no international laws or treaties designed for regulation. (<http://lawdigitalcommons.bc.edu/cgi/viewcontent.cgi?article=2175&context=ealr>)

**Effects of icebergs on climate change**

As the earth warms, sea levels rise and more fresh water joins the ocean from melted ice shelves and icebergs. This article describes how this destabilizes ocean currents that bring warm water to Northern Europe and the effects on climate and marine life. (<http://www.sciencemag.org/news/2016/06/crippled-atlantic-currents-triggered-ice-age-climate-change>)

Robert Brears, founder of the climate think tank *Mitidaption*, describes how towing an iceberg to the parched Saudi Arabian peninsula may produce climate change. He suggests that cold air from icebergs will initiate rainstorms. (<http://www.newsweek.com/iceberg-move-expert-climate-change-dubai-uae-south-pole-antarctica-610623>)



**Teacher's Guide for**

### *“Toxic Shorelines: The Science of Algal Blooms”*

**April/May 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Solution concentration** | Students may have difficulty interpreting concentration units such as parts per billion (ppb). This article provides students with a real-life application of the importance of measuring extremely small changes in conditions at the ppb level. |
| **Reaction rates** | Temperature plays an important role in the rate of chemical reactions, and this is exemplified by the change in the rate of algal growth and the production of their toxins as the seasons change. |
| **Covalent bonding** | Microcystins bind to protein phosphatase enzymes in the body with covalent bonds and cause destruction of liver cells. This example, showing a biological application of covalent bonding, may interest students as more unusual or memorable than typical carbon-hydrogen bonds. |
| **Enzymes** | Enzymes, biological catalysts, regulate most biochemical reactions, including the protein phosphatase enzymes described in the article. The article emphasizes the importance of enzymes in maintaining DNA repair and normal cell death. |
| **Solubility** | The low solubility of many phosphorus compounds found in fertilizers had typically required them to be tilled (dug into the ground) to facilitate their absorption by plants. The article emphasizes how current farming techniques allow more of the phosphorus compounds to dissolve, thus increasing algae growth in lakes. |
| **Adsorption** | The article illustrates the role and use of activated charcoal as an *ad*sorbent to purify drinking water by removing toxins and particulates from the water as it flows through the charcoal.  (Note: this is *not* absorption.) |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5**: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., *force, friction, reaction force, 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 April/May 2018 issue:

Food Chemistry

Structural Formulas

Chemical Reactions

Reaction Rates

Oxidation & Reduction

Distillation

Environmental chemistry

* Some of the articles in this issue provide information to help students consider their impact on the environment.
* Consider asking students to read “Open for Discussion: Weighing in on calories” to learn about calories in food prior to reading the article “The Protein Myth: Getting the Right Balance.”
* Students may find the infographic on page 19, “As a Matter of Fact: The Aroma of the Seaside” interesting after reading the article “Toxic Shorelines: The Science of Algal Blooms.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their choices regarding food or water use. Also, ask them if they have questions about some of the issues discussed in the articles.
* The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.

# Reading Supports for Students

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

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

* **Anticipation Guide (p. 8):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

***NEW!!!***

Instead of using Anticipation Guides for all articles, consider these ideas to engage your students in reading.

* Before reading, ask them what problems algal blooms in water might cause and how algal blooms might be treated.
* As they read, students should determine if their ideas were confirmed in the article. They can also add to their list of problems caused by algal blooms and possible solutions to the problems.
* **Graphic Organizer (p. 9):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

* **Student Reading Comprehension Questions (p. 10-11):** 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 Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“Toxic Shorelines: The Science of Algal Blooms", *ChemMatters*, April/May 2018

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

## Anticipation Guide

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

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Algae can cause health problems through skin contact or breathing. |
|  |  | 1. Algae produce less than 10% of the oxygen in the Earth’s atmosphere. |
|  |  | 1. Toxins produced by algae can cause liver damage. |
|  |  | 1. Toxins become less concentrated at each level of the food chain. |
|  |  | 1. Dead algae cause environmental damage. |
|  |  | 1. Cleaning up point-source pollution is more difficult than cleaning up nonpoint source pollution. |
|  |  | 1. The Clean Water Act of 1972 helped reduce the amount of phosphorus released into lakes in the 1970s and 1980s. |
|  |  | 1. Activated carbon can help remove toxins produced by algae. |
|  |  | 1. Algae blooms create “dead zone” in the Gulf of Mexico every year. |
|  |  | 1. Cover crops can help reduce the amount of phosphorus runoff from fields. |

## Graphic Organizer

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

“Toxic Shorelines: The Science of Algal Blooms", *ChemMatters*, April/May 2018

**Directions**: ***As you read***, complete the graphic organizer below to explain how algal blooms cause problems.

|  |  |  |
| --- | --- | --- |
|  | **Describe what it is, or where it comes from** | **What problems does it cause?** |
| ***Microcystins*** |  |  |
| ***Eutrophication*** |  |  |
| ***Point-source pollution*** |  |  |
| ***Nonpoint source pollution*** |  |  |
| ***Phosphorus*** |  |  |
| ***Domoic acid*** |  |  |

**Summary:** On the back of this paper, write a once-sentence summary (15-18 words) describing the chemistry of algal blooms.

## Student Reading Comprehension Questions

“Toxic Shorelines: The Science of Algal Blooms", *ChemMatters*, April/May 2018

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

Name

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

1. What was the cause of the 2014 Toledo, Ohio, drinking water crisis?
2. How much of the Earth’s oxygen is produced by algae?
3. What are microcystins?
4. Explain the process of biomagnification.
5. Why did the drinking water problem in Toledo occur during the summer?
6. (a) Describe the process of eutrophication, and (b) explain why it can be a problem.

**Student Reading Comprehension Questions, cont.**

“Toxic Shorelines: The Science of Algal Blooms", *ChemMatters*, April/May 2018

1. (a) Explain the difference between point-source and nonpoint-source pollution, and (b) give an example of each.
2. (a) What is the “dead zone” in the Gulf of Mexico, (b) what causes it, and (c) what is its effect?
3. (a) What is the Environmental Protection Agency’s safe adult drinking water concentration for microcystins, and (b) what was the level in Toledo’s water in 2014?
4. (a) What is domoic acid, and (b) what are its effects?
5. How does activated carbon help remove pollutants from water?
6. List three actions that farmers can take to reduce phosphorus runoff from their agricultural fields.

## Answers to Student Reading Comprehension Questions

1. **What was the cause of the 2014 Toledo, Ohio, drinking water crisis?**

*The 2014 Toledo, Ohio, drinking water crisis was caused by toxins released by algae in Lake Erie, making the water unsafe to drink.*

1. **How much of the Earth’s oxygen is produced by algae?**

*About half of the oxygen in the Earth’s atmosphere is produced by algae.*

1. **What are microcystins?**

*Microcystins are toxins produced by some algae that travel to the liver and bind to and inhibit protein phosphatase enzymes, causing destruction of liver cells.*

1. **Explain the process of biomagnification.**

*Biomagnification is a process in which toxins are passed through food chains, and at each level of the food chain, the toxins become more concentrated.*

1. **Why did the drinking water problem in Toledo occur during the summer?**

*The drinking water problem in Toledo occurred during the summer because the algae,* Microcystis aeruginosa*, depend on warm water temperatures for reproduction, so they grow rapidly in the summer.*

1. **(a) Describe the process of eutrophication and (b) explain why it can be a problem.**
   1. *Eutrophication is an aerobic process where dead algae sink to the bottom of the lake and are decomposed by bacteria.*
   2. *These bacteria consume the water’s oxygen needed by other animals to survive.*
2. **(a) Explain the difference between point-source and nonpoint-source pollution, and (b) give an example of each.**
   1. *Point-source pollution comes from a single source, while nonpoint-source pollution does not come from a single, identifiable source.*
   2. *An example of point-source pollution is sewage released from a single pipe or source. An example of nonpoint-source pollution is fertilizer run-off from agricultural operations.*
3. **(a) What is the “dead zone” in the Gulf of Mexico, (b) what causes it, and (c) what is its effect?**
   1. *The Gulf of Mexico “dead zone” is the result of numerous huge algae blooms which deplete oxygen in the water when the algae die and decompose, depleting (sucking up) the oxygen.*
   2. *It is caused by agricultural fertilizer runoff carried by the Mississippi River into the Gulf of Mexico.*
   3. *The dead zone’s effect is that it drives away or suffocates fish and other organisms.*
4. **(a) What is the Environmental Protection Agency’s safe drinking water concentration for microcystins, and (b) what was the level in Toledo’s water in 2014?**
   1. *The Environmental Protection Agency’s safe adult drinking water concentration for microcystins is 1.6 parts per billion (ppb).*
   2. *The concentration in Toledo’s water in 2014 was 2.5 ppb.*
5. **(a) What is domoic acid, and (b) what are its effects?**
   1. *Domoic acid is a powerful neurotoxin produced by algae that causes disruptions to the brain and other organs.*
   2. *It can cause short-term memory loss, seizures, and even death.*
6. **How does activated carbon help remove pollutants from water?**

*Activated carbon (charcoal) adsorbs pollutants from water by causing the pollutants to cling to the surfaces of the carbon as the polluted water flows through the carbon.*

1. **List three actions that farmers can take to reduce phosphorus runoff from their agricultural fields.**

*Three actions that farmers can take to reduce phosphorus runoff from agricultural fields include:*

* 1. *better managing the timing and amount of fertilizer they use, to reduce the amount of excess phosphorus;*
  2. *planting cover crops to reduce runoff and erosion; and*
  3. *adding extra strips of vegetation around the edges of fields to hold soil and water in place.*

# Possible Student Misconceptions

1. **“All algae are harmful.”** *Only a small percentage of algae are harmful due to the presence of the toxins they produce. Algae are responsible for producing about 50% of the oxygen in the Earth’s atmosphere. Some algae may be unsightly, or it may change the water’s taste or odor, and impact the recreational and drinking water quality, but they may not be toxic. Some algal blooms are harmful to some forms of ocean life, but may not be harmful to humans. Algae are normal parts of the ecosystem and serve as food for aquatic creatures.*
2. **“Algae blooms only occur in the summer.”** *Algae blooms occur most frequently in the summer when temperatures for rapid growth, ample sunlight, and supplies of nutrients are at their peaks. However, algae blooms can occur anytime and anyplace that conditions favor rapid growth of the algae. Warmer water due to climate change, or environmental conditions such as water warmed from a power plant or industrial facility, may provide the right conditions for rapid algae growth.*
3. **“All algae blooms are caused by fertilizer runoff from agriculture.”** *Algae are photosynthetic, so they require proper sunlight along with nutrients like nitrogen and phosphorus. The nutrients may come from agricultural runoff, but farmers have been trained in the proper application of fertilizers to minimize wastes, costs, and harmful effects. Homeowners who misapply lawn fertilizers can contribute to nutrient runoff into nearby water sources. In addition, improper handling of human fecal wastes or animal manure can allow these nutrients to accumulate in water sources. Municipal sewage accidents, improperly functioning home septic systems, and large animal feedlots or operations near water can also cause algae blooms.*

# Anticipating Student Questions

1. **“Are red tides and algae blooms the same thing?”** *A red tide is a type of algae bloom caused by specific types of algae. Some of these algae or phytoplankton cause the huge algal mass to be red or brown in color. Many people call any algae bloom a red tide, but the preferred term is* harmful algal bloom *(HAB). Some algae blooms discolor the water but are not harmful.*
2. **“Why are children more susceptible to harmful algae toxins?”** *Children often have more sensitive skin, so they react more quickly or more severely than adults when exposed. In addition, children are more likely to accidentally swallow or inhale water when swimming, making them more susceptible to algae toxin poisoning.*
3. **“How can I protect myself from exposure to harmful algal blooms?”** *The main protection is to avoid wading, swimming, or other water-contact activities when algae scums, mats, or cyanobacteria blooms are present. Don’t eat, drink, cook, or wash with untreated surface water from these areas. Common water purification methods such as boiling, filtering, or treating contaminated water do not remove the toxins. Don’t consume shellfish, or bivalves from these areas, and limit or avoid eating fish from contaminated areas. Seek medical attention if you think you or a pet may have been poisoned by these toxins.*
4. **“How can you recognize or detect toxins from harmful algae?”** *It’s not easy to detect or determine if cyanotoxins are present in water. The presence of cyanotoxins or harmful bacteria cannot be detected by observation alone. It is difficult for most people to identify types of algae by sight. Usually, detecting cytotoxins requires collecting and analyzing water samples in a laboratory. However, there are some commercially available test kits to detect the presence of cyanotoxins that do not require extensive training, if that is a necessity or preference.*
5. **“The article mentions large bodies of water like Lake Erie, the West Coast (Pacific Ocean), and the Gulf of Mexico. Do small lakes or bodies of water get algae blooms?”** *Yes! Oftentimes, smaller bodies of water (ponds, lakes, rivers) are more susceptible to algae problems than much larger bodies of water like oceans. Because of their much smaller size and volume of water, these smaller bodies of water heat up more quickly, may have a higher concentration of nutrients, and have less oversight by regulating authorities than larger bodies of water. The article focuses on the larger bodies of water because their effects are more widespread and receive more publicity.*

# Activities

**Labs and demos**

“Effect of Nitrate and Phosphate Levels on the Growth of Algae” lab**:** This five-day lab activity from the American Society for Microbiology provides complete student and teacher handouts and support for students as they study the effects of these nutrients on algal (*Chlorella*) growth. (<https://www.asm.org/images/Education/K-12/mda-algaebwpdf.final.pdf>)

**Lab activity to illustrate parts per million (ppm) and parts per billion (ppb):**  While the Earth System Research Laboratory at the National Oceanic and Atmospheric Administration (NOAA) considers it a math lesson, this lab to produce serial dilutions and understand small concentrations of gases in the atmosphere easily assists students with understanding the ppb concentrations in the algae article. The teacher worksheet provides helpful information and student answers, while the student worksheet includes background, analysis and comprehension questions, and math calculations. (Teacher link: (<https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/Teacher_MAA_understanding_ppm_and_ppb.pdf>; student link: <https://www.esrl.noaa.gov/gmd/outreach/info_activities/pdfs/MAA_understanding_ppm_and_ppb.pdf>)

**Simulations**

**“Biomagnification” virtual lab simulation:** This simulation from Virtual Biology Lab allows students to manipulate conditions and see how DDT in near-shore waters bioaccumulates through the food chain, culminating in pelicans. Select the tab “Model Info” at the bottom of the page to learn how to use the simulation. (<http://virtualbiologylab.org/NetWebHTML_FilesJan2016/BiomagnificationModel.html>)

**Media**

**“What Makes Blue-Green Algae Dangerous?—Speaking of Chemistry” video (3:53):** *Reactions* from ACS provides this video, with a quick and interesting explanation of the chemistry of an algal bloom and its toxins. The information accompanying the video includes links to related Web sites for algae blooms. (<https://www.youtube.com/watch?v=kNL99XVJjQo>)

**“Overview of Apoptosis” (10:48),** ***Khan Academy* video lesson:** The Heisman algae article uses the term *apoptosis*, and this lesson provides a discussion of this normal, programmed death of cells. A written summary of the highlights of apoptosis accompanies the video. (<https://www.khanacademy.org/science/biology/developmental-biology/apoptosis-in-development/a/apoptosis>)

**Lessons and lesson plans**

**Harmful algal blooms (HAB) lesson plan:** “Bad Algae!” is a two-day high school biology lesson provided by the Ocean Service Education division of NOAA that focuses on what are harmful algal blooms and what can be done about them. This NGSS lesson includes background information, learning procedures, a personal student connection, extensions, resources, and links to more information. (<https://oceanservice.noaa.gov/education/lessons/bad_algae.html>)

**Dead zones 5-E lesson:** This lesson from *Teach Ocean Science* leads students through activities (including a lab) to understand dead zones in water and their effects. The lesson includes instructor directions, downloadable student worksheets, and additional resources. (<http://www.teachoceanscience.net/teaching_resources/education_modules/dead_zones/access_classroom_resources/>)

**Lesson unit on harmful algal blooms:** This series of five lessons, “Fitting in the Food Web”; “Building a Bloom”; “Tracing the Toxins”; “Help! It’s a HAB!”; and “A Community in Crisis” all coordinate with Bigelow Laboratory’s *Toxic and Harmful Algal Bloom* Web site, providing numerous resources and links to more resources. In the unit, students learn about HABs and culminate with a town meeting. (<https://archive.bigelow.org/edhab/index.html>)

**Projects and extension activities**

**Understanding and describing the ecological implications of harmful algal blooms:** *Project Oceanography* publishes the 2001 unit “Unit III Red Tide and Harmful Algal Blooms”, providing students with information and general guidelines to observe algal growth in response to varying nutrient levels, explain water quality changes caused by algal growth, and assess the potential effects of water quality on an ecosystem. Student procedures, extensions, and limited teacher support are included. (<http://www.marine.usf.edu/pjocean/packets/sp01/sp01u3p2.pdf>)

**Research and study of contamination of local bodies of water:** Students could use the Thirteen Online project “Contaminated Water”, shifting the original lesson’s broad approach on water pollution, to a focus on algae as the primary contaminant, for an extended project. The Web site provides possibilities for procedures, objectives, assessment, computer resources, additional Web sites, and a guide to help students use “the” scientific method of investigation. (<http://www.thirteen.org/edonline/wue/water1_overview.html>)

# References

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

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



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

Available Now!

The 2009 article “Those Blooming Algae!” addresses topics similar to the Heisman article. This article discusses a red tide in the Gulf of Mexico in 2004, possible causes for algal blooms, and a potentially beneficial compound extracted from a species of algae. (Baxter, R. Those Blooming Algae! *ChemMatters*, 2009, *27* (2), pp 10–12)

The April 2009 Teacher’s Guide for “those Blooming Algae!” (See above) provides background information on algae and phytoplankton, ocean chemistry, algae and nutrient stimulation, reducing atmospheric carbon dioxide by photosynthesis, and using algae as a biofuel.

“Nitrogen from Fertilizers: Too Much of a Good Thing” provides additional information on the other primary nutrient involved in algal blooms, nitrogen. The article addresses the nitrogen cycle, excess fertilizers causing environmental damage (including to oceans), and a sidebar on the Haber-Bosch synthesis of ammonia. (Nolte, B. Nitrogen from Fertilizers: Too Much of a Good Thing. *ChemMatters*, 2010, *28* (4), pp 5–7)

Read about using algae as a renewable source for extracting hydrocarbons to produce fuel for powering vehicles in “From Fish Tank to Fuel Tank”. The article provides a chemical reaction for forming an algal precursor to biodiesel and a chart comparing the attributes of using algae, soybeans, corn kernels, and corn stalks as sources of plant-derived fuels. (Hill, M. From Fish Tank to Fuel Tank. *ChemMatters*, 2012, *30* (4), pp 12–14)

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“Investigating Aquatic Dead Zones” is a high school activity published by *The Science Teacher* to investigate the concept of a dead zone, and it includes the procedure, materials list, teaching hints, and student questions. Another activity in the article looks at dead zones from the concept of density as it relates to stratification of the water. (Testa, J; et al. Aquatic Dead Zones. *The Science Teacher*, 2010, *77* (2), pp 29–34; <http://static.nsta.org/files/tst1002_29.pdf> Note that this link may take you to a brief abstract only; the full article is only available to National Science Teachers Association members or subscribers to one of its journals.)

“Reducing Phosphorus to Curb Lake Eutrophication Is a Success” details the success of decreasing lake eutrophication by controlling phosphorus in nine countries. Controlling nitrogen inputs were less successful than controlling phosphorus inputs to the lakes. (Schindler, D.; et al. Reducing Phosphorus to Curb Lake Eutrophication Is a Success. *Enviro. Sci. Technol.*, 2016, *50* (17), pp 8923–8929; <http://pubs.acs.org/doi/10.1021/acs.est.6b02204>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

# Web Sites for Additional Information

**Blue-green algae (cyanobacteria)**

The Environmental Protection Agency (EPA) provides information on cyanobacteria and cyanotoxins, including a description of cyanobacteria and cyanotoxins, what species of cyanobacteria produce toxins, the most common U.S. cyanotoxins, and additional information. The information can be found at <https://www.epa.gov/nutrient-policy-data/cyanobacteriacyanotoxins>.

Purdue University and Wichita State University host a Web site, *Cyanosite,* devoted to cyanobacteria*.* This site has links to “Cyanobacteria Image Gallery”, “Culture Media Recipes”, “Toxic Cyanobacteria”, “Experimental Protocols”, “Cyanobacteria Taxonomy”, “CyBib Bibliographical Archive”, and “Annotated Links”, with rich information in each link. (<http://www-cyanosite.bio.purdue.edu/>)

“Cyanobacteria and Cyanotoxins: From Impacts on Aquatic Ecosystems and Human Health to Anticarcinogenic Effects” is a 2013 review of the negative and beneficial effects of cyanobacteria and their toxins. This review includes 95 references and contains some in-depth information. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3813918/>)

**Harmful algal blooms (HAB)**

“Human Health Effects from Harmful Algal Blooms: a Synthesis” is a 2013 report by Canadian and U.S scientists focused on the Great Lakes. Contents of the HAB report include background information, occurrence and distribution, human health effects, risks from exposure, economic effects, and more. (<http://www.ijc.org/files/publications/Attachment%202%20Human%20Health%20Effects%20from%20Harmful%20Algal%20Blooms.pdf>)

***Microcystis* algae**

“Effect of Light Exposure and Nutrients on Buoyancy of *Microcystis* Colonies”, a poster presentation from the University of Michigan’s School of Natural Resources and Environment, presents data and conclusions on a study of the vertical distribution of *Microcystis* harmful algal blooms in Lake Erie. (<https://www.glerl.noaa.gov/pubs/posters/Ming_IAGLR_2017.pdf>)

**Microcystins**

“*Microcystis aeruginosa* and the Effects of Microcystin-LR on Ecosystems and Human Health” looks at the organism and the toxin described in the Heisman article that were responsible for the Toledo, Ohio, water crisis in 2014. Dangers to humans, ecosystems, and a chemical structure of microcystin-LR are provided. (<https://microbewiki.kenyon.edu/index.php/Microcystis_aeruginosa_and_the_Effects_of_Microcystin-LR_on_Ecosystems_and_Human_Health>)

An information sheet from the Iowa Department of Public Health provides answers to frequently asked questions about cyanobacteria and microcystin toxins. (<https://www.idph.iowa.gov/Portals/1/Files/EHS/algae_faq.pdf>)

**Apoptosis**

Biology textbook author John Kimball provides online information about cell death. His explanation of the two types of cell death, from injurious agents or suicide, provides information on the mechanisms of apoptosis—with diagrams, connections to cancer and immune systems, and links to additional information. (<http://www.biology-pages.info/A/Apoptosis.html>)

**Biomagnification**

*Earth Eclipse* supplies “What Is Biomagnification?”—an easy to understand explanation. Causes, effects, and the process of biomagnification are parts of the information supplied. (<https://www.eartheclipse.com/ecosystem/causes-effects-process-of-biomagnification.html>)

*PolarTREC* hosts the activity “Bioaccumulation of Toxins”, which allows students to use marshmallows to simulate environmental toxins to model bioaccumulation in a food chain. The activity provides the student worksheet, photocopy handouts, procedures, and sample student answers. (<https://www.polartrec.com/files/resources/lesson/10856/docs/bioaccumulation_toxins_final_1.pdf>)

**Climate change and algal growth**

The EPA published a 2013 document, “Impacts of Climate Change on the Occurrence of Harmful Algal Blooms”, that describes how changes in temperature, salinity, carbon dioxide, rainfall, and other factors may impact HABs. (<https://www.epa.gov/sites/production/files/documents/climatehabs.pdf>)

“Algae, Cyanobacteria Blooms, and Climate Change” examines the causes and results of algal blooms and changing climate conditions. The 2017 article from the Climate Institute provides diagrams, some data, charts, and references. (<http://climate.org/wp-content/uploads/2017/05/bennett_algalblooms-1.pdf>)

**Point-source and nonpoint-source pollution**

The EPA supplies a Web site, *Polluted Runoff: Nonpoint Source Pollution,* which includes the tabs “Restore & Protect” and “Learn”. The “Learn” tab has links to “What is Nonpoint Source”, “Types of Nonpoint Source”, and “Education Materials for Students”. (<https://www.epa.gov/nps>)

NOAA provides information on pollution, including both point source and nonpoint source. Information and pictures provided in numerous links present understandable content on these pollution types. (<https://oceanservice.noaa.gov/education/kits/pollution/03pointsource.html>)

**Domoic acid**

For a one-page description of domoic acid: its chemical structure, distribution, mode of action, effects on human health, and effects on other organisms, see <http://www.nmfs.noaa.gov/pr/pdfs/health/domoic_acid.pdf>.

Domoic acid may have been the cause of bizarre bird behavior and deaths in 1961 in the Santa Cruz, CA, region, and the inspiration for Alfred Hitchcock’s horror movie “The Birds”. (<https://www.livescience.com/17713-hitchcock-birds-movie-algae-toxin.html>)

**Dead zones**

An NOAA media release from August 2017 provides information on the New Jersey-sized dead zone in the Gulf of Mexico that year. The release includes a diagram showing the size and oxygen concentrations in the water, with embedded links in the news release. (<http://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured>)

*National Geographic* supplies the article “Dead Zone”, teaching readers about natural dead zones, as well as those caused by pollution. An explanation of eutrophication, environmental factors, photographs, and additional links enhance the article. (<https://www.nationalgeographic.org/encyclopedia/dead-zone/>)

**Eutrophication**

“Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems”, furnished by *Nature,* provides a complete overview of eutrophication with photos and explanations. The Web site also includes an extensive reference list and recommendations for further reading. (<https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466>)

**Phosphorus pollution**

The*Lake Erie Algae* Web site from Heidelberg University (Toledo, Ohio) covers 45 years of Lake Erie algae and pollution, including: “The History of Lake Erie’s Troubles”, “How Do We Know Phosphorus Is the Culprit?”, “Point Source vs Non-Point Source Pollution”, “Why Is dissolved phosphorus such a problem for Lake Erie?”, and “The Way Forward”. The video “A Tale of Two Rivers: Lake Erie Algae” (6:31) examines how phosphorus from the Maumee and Cuyahoga Rivers watersheds impact the algal growth. (<http://lakeeriealgae.com/>)

This comprehensive 2018 article in the *Water Resources Research* journal describes the worldwide effects of human activities on phosphorus pollution and the results in freshwater systems. The article, “Global Anthropogenic Phosphorus Loads to Freshwater and Associated Grey Water Footprints and Water Pollution Levels: A High-Resolution Global Study”, looks at phosphorus pollution from mineral-based and manure-based fertilizers and from wastewater, and it provides explanations, tables, and useful charts, breaking down information by countries, pollution sources, and 20 major river basins. (<http://onlinelibrary.wiley.com/doi/10.1002/2017WR020448/full>)

**Toledo’s water crisis**

A Toledo newspaper, *The Blade*, publishes the Web site *Toledo’s Water Crisis*, with articles, photos, and videos of the August 2014 drinking water crisis, arranged daily or weekly from August 2–23, 2014. Abundant information arranged by headline and type of resource is linked to the site. (<http://www.toledoblade.com/watercrisis>)

The City of Toledo hosts a Web site, *Toledo Water Quality*, with a color-coded gauge indicating the current quality of the drinking water supply. Links on the page include “Frequently Asked Questions”, “Toledo Water Test Results”, and “Water Treatment (with sub links)”. (<http://toledo.oh.gov/services/public-utilities/water-treatment/water-quality/>)

**Inhibitors**

The *LibreText* “Chemistry” Web page presents "Drugs as Enzyme Inhibitors," which complements the Heisman article. Penicillin is used as an example of an inhibitor interfering with the action of an enzyme, similar to the microcystins blocking protein phosphatase enzymes. (<https://chem.libretexts.org/Textbook_Maps/Organic_Chemistry_Textbook_Maps/Map%3A_Organic_Chemistry_(Bruice)/31%3A_The_Organic_Chemistry_of_Drugs%3A_Discovery_and_Design/31.07%3A_Drugs_as_Enzyme_Inhibitors>; note: readers may need to register for free to access some information.)

The *Khan Academy* supplies a great lesson, "Enzyme Regulation." The content explains cofactors and coenzymes; reversible, irreversible, competitive, and noncompetitive inhibitors; allosteric enzymes; and feedback inhibition, with diagrams and text. (<https://www.khanacademy.org/science/biology/energy-and-enzymes/enzyme-regulation/a/enzyme-regulation>

**Concentrations (parts per million or billion)**

The lab activity “Using Serial Dilution to Understand ppm/ppb” is adapted from a SEPUP lesson, and its objectives include defining ppm and ppb, and understanding that a contaminant may be present even when it’s not visible. (<https://sph.unc.edu/files/2013/07/serial_dilution_activity_2012.pdf>)

This link is a straight-forward explanation of small concentrations (e.g., ppm, ppb), using comparisons, conversions, and example quantities for solids and liquids. The example toxin is PCB, but the information is applicable to any substance. (<http://pmep.cce.cornell.edu/profiles/extoxnet/TIB/ppm.html>)

**Reaction rates and temperature**

“The Effect of Temperature on Reaction rates” explains collision frequency and activation energy, due to temperature changes on reaction rate. The site includes appropriate high school-level information with diagrams and examples. (<https://www.chemguide.co.uk/physical/basicrates/temperature.html>)

The *LibreText* “Chemistry” Web page provides “Changing Reaction Rates with Temperature” for another explanation of the effect of temperature on reaction rates. It, too, has a diagram to support the text, as well as links to two videos and three questions to check reader comprehension. (<https://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Kinetics/Modeling_Reaction_Kinetics/Temperature_Dependence_of_Reaction_Rates/Changing_Reaction_Rates_with_Temperature>)

**Covalent bonding**

The PBS Web site *Covalent Bonding* includes a 35-screen student interactive, “Covalent Bonding Tutorial”, support materials explaining covalent bonds, and discussion questions for student use. Educational standards for the materials are provided for teachers. (<https://aetn.pbslearningmedia.org/resource/lsps07.sci.phys.matter.covalentbond/covalent-bonding/#.Wm-FhKinFhE>)

*ChemGuide* has the Web page, “Covalent Bonding – Single Bonds”, with a clear explanation of this phenomenon. The page includes “A Simple View of Covalent Bonding”, with text and dot-diagrams, as well as “A More Sophisticated View of Covalent Bonding”, and “Hybridisation”. (<https://www.chemguide.co.uk/atoms/bonding/covalent.html>)

**Adsorption**

The Web site *Diffen* publishes a comparison chart of absorption and adsorption, along with explanations, diagrams, and the video “Absorption and Adsorption” (4:53). The site also provides examples of uses of these two processes. (<https://www.diffen.com/difference/Absorption_vs_Adsorption>)

A more scientific explanation of adsorption comes from *Chemistry Learning*. Information on adsorption in liquids and solids, free energy, adsorption factors with mathematical formulas, and useful diagrams are provided. (<http://www.chemistrylearning.com/adsorption/>)

# About the Guide

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

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

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

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