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**October 2014 Teacher's Guide**

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# About the Guide

Teacher’s Guide editors William Bleam, Donald McKinney, and Ronald Tempest created the Teacher’s Guide article material. E-mail: [bbleam@verizon.net](mailto:bbleam@verizon.net)

Susan Cooper prepared the national science education content, anticipation guides, and reading guides.

David Olney created the puzzle.

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

Patrice Pages, *ChemMatters* editor, coordinated production and prepared the Microsoft Word and PDF versions of the Teacher’s Guide. E-mail: [chemmatters@acs.org](mailto:chemmatters@acs.org)

Articles from past issues of *ChemMatters* can be accessed from a CD that is available from the American Chemical Society for $30. The CD contains all *ChemMatters* issues from February 1983 to April 2008.

The *ChemMatters CD* includes *an* Index that covers all issues from February 1983 to April 2008.

The *ChemMatters* CD can be purchased by calling 1-800-227-5558.

Purchase information can be found online at [www.acs.org/chemmatters](http://chemistry.org/chemmatters/cd3.html)

# Student Questions (from the articles)

**The Sweet Science of Candymaking**

* 1. Name the three types of candy textures.
  2. What is the main difference in the structures of rock candy and fudge?
  3. What is the composition of sucrose?
  4. Why do sucrose molecules dissolve in water?
  5. What are the two steps involved in dissolving a solid?
  6. When a solid dissolves, is that all that is happening? Explain.
  7. Is anything happening when a solution is saturated? Explain.
  8. How does Le Châtelier’s principle explain why a temperature increase causes more sugar to dissolve in an already saturated solution?
  9. What is a supersaturated solution?
  10. How does stirring result in candy’s fudge-like consistency?
  11. How does one get a glassy texture in candy?
  12. What makes cotton candy different from other types of sugar-based candies?
  13. What are the two main factors involved in the varied textures of candy?

**Performance-Enhancing Drugs: Is Winning Everything?**

1. What per cent of high school students report using PEDs?
2. What is dysmorphia?
3. What was Alex Rodriguez’ penalty for using performance-enhancing drugs?
4. Are anabolic steroids naturally-occurring or synthetic?
5. What chemical structure is common to all steroids?
6. Name the steroid hormone that many PEDs mimic.
7. Describe the two steps by which anabolic steroids build muscle.
8. Identify the PED that is involved with blood doping.
9. List some of the serious medical issues caused by the abuse of PEDs.
10. Are there legitimate medical uses for PEDs like anabolic steroids and EPO?

**The Starting Line of a Drug-Free Athlete**

1. Identify the negative symptoms Efrain Marrero experienced when he began to inject steroids.
2. Name the two University of Oregon Health and Science University professors who founded ATLAS/ATHENA program.
3. What is the purpose of ATLAS/ATHENA?
4. Who are the teachers in the ATLAS/ATHENA program?
5. Why are there two different programs—one for males and one for females?
6. What is the origin of the names for the program?

**Do You Know about BVO?**

1. What is BVO?
2. Why is BVO added to soft drinks?
3. What is the oil in soft drinks that requires BVO for mixing the oil with water?
4. Why will the flavoring agent, citrus oil, dissolve in BVO but not in the water of the soda?
5. Why does adding bromine increase the density of vegetable oil?
6. What are the effects of the element bromine when in contact with or in close proximity to human tissue?
7. What is the association between ingesting bromine in compounds (such as sedatives) and the function of the thyroid and the brain?
8. What is the evidence that consuming BVO-containing drinks on a casual basis will produce the same symptoms as found in those people who consume very large amounts of drinks with BVO in them?
9. What are the alternatives to BVO that are currently being used by various soda manufacturers?
10. What are emulsifiers and how do they work?

**Shampoo: From Lab to Shower**

* 1. What is the “dirt” in our scalps that we are trying to remove with shampoo?
  2. What is sebum and what does it do for our body?
  3. What factors determine how dirty our hair might be at the end of the day?
  4. What is the relationship between hair shape and its oiliness?
  5. How does a surfactant in shampoo help to spread water over the hair?
  6. What is the mechanism by which surfactant molecules get oil molecules to mix with water?
  7. What is a micelle?
  8. How do the two most popular surfactants in shampoo differ in their behavior?
  9. Name two other important ingredients and their functions in shampoo, other than water and surfactants.
  10. Why are cationic polymers good conditioners for shampoo but also a potential problem in use?

# Answers to Student Questions (from the articles)

**The Sweet Science of Candymaking**

* + 1. **Name the three types of candy textures, according to the article.**

*The three textures of candy are chewy, gritty and hard.*

* + 1. **What is the main difference in the structures of rock candy and fudge?**

*The main difference in structure between rock candy and fudge is the size of the sugar crystals—in rock candy, the crystals are very large, while in fudge they are very small.*

* + 1. **What is the composition of sucrose?**

*Sucrose is a disaccharide composed of one each of the monosaccharides glucose and fructose.*

* + 1. **Why do sucrose molecules dissolve in water?**

*Sucrose molecules dissolve in water because the water molecules attract the sucrose molecules through intermolecular forces.*

* + 1. **What are the two steps involved in dissolving a solid?**

*These steps are involved in dissolving a solid:*

* + - 1. *Water molecules bind to sucrose molecules on the crystal’s surface, and*
      2. *The water molecules pull those sucrose molecules away from the crystal into solution.*
    1. **When solid sucrose dissolves, is that all that is happening? Explain.**

*When solid sucrose dissolves, there is also re-crystallizing taking place as sucrose molecules in solution rejoin the crystal. But the rate of dissolving is greater than the rate of re-crystallization.*

* + 1. **Is anything happening when a solution is saturated? Explain.**

*When a solution is saturated, dissolving and re-crystallizing are still happening, but the two rates are equal, so the two processes are balanced and no net change occurs.*

* + 1. **How does Le Châtelier’s principle explain why a temperature increase causes more sugar to dissolve in an already saturated solution?**

*Le Châtelier’s principle, which states that an equilibrium system that is shifted away from equilibrium acts to restore equilibrium by opposing the shift, explains an increase in the amount of sugar dissolved at an increased temperature by noting that*

1. *an increase in temperature increases the energy of the system;*
2. *the system reacts to reduce temperature/energy within the system by cooling down;*
3. *breaking chemical bonds requires energy, thus reducing the energy of the system, so sugar molecules break apart and dissolve into the solution as equilibrium is restored.*
   * 1. **What is a supersaturated solution?**

*A supersaturated solution is a solution containing more solid than can stay dissolved at a specific temperature.*

* + 1. **How does stirring result in candy’s fudge-like consistency?**

*Stirring the hot solution produces large numbers (VERY large numbers!) of tiny seed crystals. Sucrose molecules dissolved in the solution then re-crystallize on these seed crystals. But because there are so many of them, the sucrose that recrystallizes has many sites on which to crystallize. The result is that all the crystals throughout the fudge remain very small, producing consistency typical of fudge.*

* + 1. **How does one get a glassy texture in candy?**

*A glassy texture in candy results from the rapid cool-down of the solution, resulting in no crystal formation. This solid structure without crystals is an amorphous or glassy structure.*

* + 1. **What makes cotton candy different from other types of sugar-based candies?**

*The main thing that makes cotton candy different from other types of sugar-based candies is that the process of making cotton candy uses heat to melt the sugar, not to dissolve it, as is the case for all other types of candy. The melted sugar is then spun into long strands of liquid that immediately solidify upon rapid cooling, resulting in an amorphous structure.*

* + 1. **What are the two main factors involved in the varied textures of candy?**

*The two main factors involved in making varied textures of candy are:*

* + - 1. *The length of time allowed for crystal growth (long time, large crystals; short time, small crystals) and*
      2. *The processing of the syrup as it cools (allow to set, large crystals; stir, small crystals; spin, no crystals).*

**Performance-Enhancing Drugs: Is Winning Everything?**

1. **What per cent of high school students report using PEDs?**

*The article indicates a 2012 figure of 3.6 % of high school students who use PEDs.*

1. **What is dysmorphia?**

*The article says that dysmorphia is a “condition where a person cannot stop thinking about perceived flaws with his or her appearance. Signs and symptoms of this disorder include feelings of distress and obsession with weight training and muscle building and can lead to substance abuse.” The article says that this disorder can lead teenagers to use PEDs.*

1. **What was Alex Rodriguez’ penalty for using performance-enhancing drugs?**

*Major League Baseball banned Rodriguez for the entire 2014 season. The article mentions that Rodriguez got his PEDs from Biogenesis of America, a Florida anti-aging company.*

1. **Are anabolic steroids naturally-occurring or synthetic?**

*Anabolic steroids are both naturally-occurring and synthetic. The article tells us that many anabolic steroids are actually naturally-occurring human hormones that promote muscle growth. However, the anabolic steroids that are PEDs are synthetic compounds that duplicate the natural compounds.*

1. **What chemical structure is common to all steroids?**

*Steroids all are organic compounds which contain three six-carbon rings and one five-carbon ring.*

1. **Name the steroid hormone that many PEDs mimic.**

*Virtually all the steroid PEDs are some synthetic variation of the male hormone testosterone. That is the reason that these PEDs are called androgenic-anabolic steroids. “Androgenic” refers to males, and the term gives rise to the abbreviation “andro.”*

1. **Describe the two** **steps by which anabolic steroids build muscle.**

*The first step by which anabolic steroids build muscle is that they enter muscle cells by diffusing through the cell membranes. Then they bind with cell protoplasm and travel to the cell nucleus to activate cell DNA that provides instructions to build muscle protein.*

1. **Identify the PED that is involved with blood doping.**

*The substance involved with blood doping is called erythropoietin (EPO). It increases the production of red blood cells.*

1. **List some of the serious medical issues caused by the abuse of PEDs.**

*The article lists several side effects of PEDs abuse: shrinking of the testicles due to the decrease in natural production of testosterone, premature baldness due to increased production of dihydrotestosterone, liver damage, heart disease and sterility and stunted growth.*

1. **Are there legitimate medical uses for PEDs like anabolic steroids and EPO?**

*Yes, legitimate medical uses for PEDs exist. Anabolic steroids are used to treat hormone imbalance, delayed puberty and anemia. Medical uses for EPO include anemia and kidney failure.*

**The Starting Line of a Drug-Free Athlete**

1. **Identify the negative symptoms Efrain Marrero experienced when he began to inject steroids.**

*The negative symptoms he experienced were depression and paranoia.*

1. **Name the two University of Oregon Health and Science University professors who founded the ATLAS/ATHENA program.**

*The two professors who began the program are Linn Goldberg and Diane Elliott.*

1. **What is the purpose of ATLAS/ATHENA?**

*The purpose of the program is to stop the use of steroids among high school students.*

1. **Who are the teachers in the ATLAS/ATHENA program?**

*The teachers are actually high school athletes who train other high school students, after they’ve been trained by adult coaches.*

1. **Why are there two different programs—one for males and one for females?**

*Males and females use PEDs for different reasons. According to the article, male adolescents use them for thrill-seeking and risk-taking reasons and females use them related to diet, weight loss and depression.*

1. **What is the origin of the names for the program?**

*ATLAS is named for the Greek mythological god Atlas who was forced to carry the world on his shoulders, and ATHENA is name for the mythological Greek goddess of wisdom.*

**Do You Know about BVO?**

1. **What is BVO?**

*BVO stands for brominated vegetable oil. BVO is created by adding bromine to vegetable oil.*

1. **Why is BVO added to soft drinks?**

*The BVO is added to soft drinks in order to keep flavoring agents (oils of various citrus fruits) suspended in the soda solution. The BVO has a density nearly equal to that of the water, keeping the oil from floating to the top.*

1. **What is the oil in soft drinks that requires BVO for mixing the oil with water?**

*The oil in soft drinks is from citrus fruits and is used for flavoring the soda drink.*

1. **Why will the flavoring agent, citrus oil, dissolve in BVO but not in the water of the soda?**

*Citrus oil dissolves in BVO but not water because water is different chemically from BVO, due to differences related to polarity (polar and non-polar) that determine if two substances mix or not. The citrus oils are non-polar and will not mix with polar water but can mix with the non-polar BVO which remains suspended in the solution.*

1. **Why does adding bromine increase the density of vegetable oil?**

*Adding bromine to vegetable oil increases the density of the (now brominated) vegetable oil because bromine is a heavy element, relative to the carbon atoms in the vegetable oil, without being much bigger than carbon, so it makes the whole new molecule heavier/denser.*

1. **What are the effects of the element bromine when in contact with or in close proximity to human tissue?**

*Bromine, by itself, can cause irritation to the eyes and lungs. It can also cause thyroid problems.*

1. **What is the association between ingesting bromine in compounds (such as sedatives) and the function of the thyroid and brain?**

*In sedatives, bromine can cause side effects such as depression, memory loss, hallucinations, tremors, and confusion. It is also thought that when rats and humans have been exposed to bromine, there is delay in brain development, early onset of puberty, and the disruption of hormone function.*

1. **What is the evidence that consuming BVO-containing drinks on a casual basis will produce the same symptoms as found in people who consume very large amounts of drinks with BVO in them?**

*There is little if any evidence and few studies done on the impact of BVO on casual consumers. (Note that this does not mean it is safe, merely that there is no evidence that it is NOT safe—the FDA is still waiting, 44 years later, for the results of the studies!)*

1. **What are the alternatives to BVO that are currently being used by various soda manufacturers?**

*Two different chemicals are being used in the USA and overseas as substitutes for BVO. One compound is sucrose acetate isobutryate and the other is glycerol ester of wood rosin.*

1. **What are emulsifiers and how do they work?**

*Emulsifiers are chemicals that help disperse other molecules in a solution. These molecules typically have both polar and non-polar ends that can interact with other molecules, both polar and non-polar, and can keep them evenly dispersed throughout the mixture.*

**Shampoo: From Lab to Shower**

1. **What is the “dirt” in our scalps that we are trying to remove with shampoo?**

*The “dirt” in our scalps is the fats and oils of sebum.*

1. **What is sebum and what does it do for our body?**

*Sebum is an oily substance secreted by the sebaceous glands inside our skin. The sebum acts as a lubricant for the hair and skin, providing some protection from bacteria.*

1. **What factors determine how dirty our hair might be at the end of the day?**

*Some of the factors affecting your hair’s “dirt” status include where you work, the amount of humidity in the air and even your ethnicity. If you live in a dry and hot area, your hair will be less oily; working at a restaurant or car mechanics means more oily hair.*

1. **What is the relationship between hair shape and its oiliness?**

*People with straight hair will tend to have oilier hair than curly haired people because oil wicks more easily from the scalp up the hair shaft of straight hair than it can in curly hair.*

1. **How does a surfactant in shampoo help to spread water over the hair?**

*Surfactants reduce the surface tension of water which helps spread water on the hair.*

1. **How do surfactant molecules get oil molecules to mix with water?**

*A surfactant’s molecular structure contains two parts: “…one attracted to water molecules and the other one attracted to oil molecules. The part that is attracted to water is called polar, and the one attracted to oil is called nonpolar. The polar part contains regions of partially negative and partially positive charges, while the nonpolar part has no partial charges.” So, the surfactant molecules can hold on to the oil molecules while also being attracted to the water molecules, thus mixing the oil with the water.*

1. **What is a micelle?**

*A micelle is a cluster of molecules formed from surfactant molecules surrounding oil molecules. These clusters are lifted out of the hair strands and washed away by the surrounding water.*

1. **How do the two most popular surfactants in shampoo differ in their behavior?**

*Both surfactants, sodium lauryl sulfate and sodium laureth sulfate, lower the surface tension of water, but sodium lauryl sulfate is more drying to the hair and removes more oils than sodium laureth sulfate.*

1. **Name two other important ingredients and their function in shampoo, other than water and surfactants.**

*Shampoo contains substances that create a lather as well as conditioning molecules which keep the hair smooth after rinsing.*

1. **Why are cationic polymers good conditioners for shampoo but also a potential problem in use?**

*Cationic polymers are good conditioners because they strongly cling to water through static attraction and are not easily removed when the hair is rinsed—great for conditioning the hair. On the other hand, these conditioners can irritate the eyes if used too frequently.*

# *ChemMatters* Puzzle: A Quote Box for Our Times

In a quote box puzzle, a thought-provoking quote has all of its letters displayed but jumbled. Your task is to decipher the message by dropping the letters provided at the top of each vertical

column into any of the available empty cells directly below it. As you proceed, the words in the

quote (reading left to right) will start to emerge in the bottom rows. A word may continue from one line to the next. A black cell represents the end of a word and may contain a comma or period.

We will give you two quotes to tackle. Their solution can be found on the “Answers” page.

A few hints for quote #1 and a gift of a letter will get you started:

* The first letter in the quote is either a T or an N. In fact it's a T and we've written it in.

The second letter completes the first word. It is either a W or an O. But “TW” is not a word, so it must be O. It follows that the W is the first letter of the first word in row 3 of the quote.

* See a three-letter word that starts with T ? Chances are it's “THE”. Look for other common words, as well as topic words such as “CHEMICAL” or “SCIENCE”.

**PUZZLE #1 The WARM-UP**

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**PUZZLE #2** This quote box uses four rows , so it is a bit longer and harder than #1. Here is a hint: the one and only appearance of the letter V is in the first word of the quote.

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# Answers to the *ChemMatters* Puzzle

#1 WARM-UP QUOTE: “To the public, most often, beliefs trump science when in conflict.”

This quote came from an Associated Press release issued April 22, 2014. It examined a recent

poll taken by 1,012 adults on whether they agreed with the views held by a large

majority of scientists on issues such as evolution, vaccinations , and climate change.

Alan Leshner, the executive secretary of the American Association for the Advancement of Science (AAAS), was cited as the source of the above quote, made upon surveying the results of the poll.

# 2 MAIN QUOTE: “Everyone is entitled to their own opinions, but they are not entitled to their own facts.”

The author of this quote is Daniel Moynihan, a one-time U.S. senator from New York State and close advisor to then-president John F. Kennedy.

SOME POSSIBLE ACTIVITIES for a classroom or a chemistry club:

1. Draw up a list of areas of science that are, on occasion, controversial, and devise a poll for the group, using choices such as “extremely confident,” “quite confident,” ”unsure,” “don't accept a scientist's claim,” etc.

2. Write a short essay explaining Moynihan's quote and giving an example from this set:

* Smoking causes cancer.
* Life on Earth evolved slowly through the process of natural selection.
* Overusing antibiotics causes drug-resistant bacteria to multiply.
* Diesel gasoline produces more greenhouse gases than regular gasoline.

# Next-Generation Science Standards (NGSS) Correlations

|  |  |
| --- | --- |
| **Article** | **NGSS** |
| **The Sweet Science of Candymaking** | |  | | --- | | **HS-PS1-5.**  Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. |   **Crosscutting Concepts:**   * Patterns * Stability and Change   **Science and Engineering Practices:**   * Constructing explanations and designing solutions * Developing and using models   **Nature of Science:**   * Science models, laws, mechanisms, and theories explain natural phenomena. |
| **Performance-Enhancing Drugs: Is Winning Everything?** | |  | | --- | | **HS-ETS1-3.**  Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.  **Crosscutting Concepts:**   * Structure and Function   **Science and Engineering Practices**:   * Constructing explanations and designing solutions   **Nature of Science**:   * Science addresses questions about the natural and material world. * Science is a human endeavor. | |
| **The Starting Line for a Drug-Free Athlete** | |  | | --- | | **HS-ETS1-3.**  Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. |   **Crosscutting Concepts:**   * Cause and Effect * Structure and Function   **Science and Engineering Practices:**   * Analyzing and interpreting data * Obtaining, evaluating, and communicating information   **Nature of Science:**   * Science addresses questions about the natural and material world. |
| **Do You Know about BVO?** | |  | | --- | | **HS-PS1-3.**  Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.  **Crosscutting Concepts:**   * Cause and Effect * Structure and Function   **Science and Engineering Practices:**   * Analyzing and interpreting data * Obtaining, evaluating, and communicating information   **Nature of Science**:   * Science models, laws, mechanisms, and theories explain natural phenomena. | |
| **Shampoo: From Lab to Shower** | |  | | --- | | **HS-PS1-3.**  Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. | | **Crosscutting Concept:**   * Structure & Function * Systems and System Models   **Science and Engineering Practices**:   * Constructing explanations and designing solutions   **Nature of Science**:   * Science models, laws, mechanisms, and theories explain natural phenomena. | |

# 

# Common Core State Standards Connections

*(for all the articles in this issue (October/December 2014))*

**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.

**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.

***In addition***, the teacher could assign writing to include the following **Common Core State Standards**:

**WHST.9-10.2** Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience’s knowledge of the topic.

**WHST.11-12.2**  Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience’s knowledge of the topic.

# Anticipation Guides

Anticipation guides help 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.

**Directions for all Anticipation Guides: *Before reading***, 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.

## The Sweet Science of Candymaking

**Directions:**  *Before reading*, 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. Different types of candies use different kinds of sugars to make the crystal size different. |
|  |  | 1. Sugars are carbohydrates. |
|  |  | 1. If you add more sugar to a saturated sugar solution, it will dissolve. |
|  |  | 1. Once a sugar molecule is dissolved, it remains as long as the conditions (temperature, amount of water, stirring, etc.) remain constant. |
|  |  | 1. Heating a sugar solution causes more sugar molecules to dissolve. |
|  |  | 1. When chemical bonds break, energy is released. |
|  |  | 1. Crystals may start to grow on a group of molecules, a speck of dust, or even a gas bubble. |
|  |  | 1. Glass candy is cooled very slowly so no crystals form. |
|  |  | 1. Marshmallows and gummy candy contain the same ingredients, but marshmallows have air whipped in. |
|  |  | 1. Cotton candy is made with sugar and water. |

## Performance-Enhancing Drugs: Is Winning Everything?

**Directions:**  *Before reading*, 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. Less than 1% of high school students report taking steroid pills. |
|  |  | 1. Anabolic steroids are synthetic drugs that promote muscle growth. |
|  |  | 1. Testosterone, estrogen, and cholesterol are steroids. |
|  |  | 1. Anabolic steroids activate genes in the DNA of the nuclei of cells. |
|  |  | 1. Anabolic steroids are the same as steroids produced naturally by the body. |
|  |  | 1. Erythropoietin (EPO) causes the bone marrow to produce more red blood cells. |
|  |  | 1. Exercise affects the pH of the blood. |
|  |  | 1. Hemoglobin molecules hold oxygen atoms as they travel around the body. |
|  |  | 1. Anabolic steroids and EPO cause more serious side effects in adults than in teenagers. |
|  |  | 1. Anabolic steroids and EPO have important medical uses. |

## The Starting Line of a Drug-Free Athlete

**Directions:**  *Before reading*, 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. Steroid use can cause extreme depression. |
|  |  | 1. Young people can be influenced by high-profile athletes. |
|  |  | 1. The ATLAS/ATHENA program is led by coaches. |
|  |  | 1. The ATLAS/ATHENA program works the same for boys and girls. |
|  |  | 1. The ATLAS/ATHENA program is going to Australia. |
|  |  | 1. Steroid hormones regulate blood pressure and carbohydrate metabolism. |
|  |  | 1. Catabolic steroids break tissue down. |
|  |  | 1. Anabolic steroids have no legitimate medical use. |
|  |  | 1. Synthetic steroids affect the normal production of hormones in the body. |
|  |  | 1. High blood pressure is a common side effect of synthetic steroid use. |

## Do You Know about BVO?

**Directions:**  *Before reading*, 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. Adding bromine decreases the density of vegetable oil. |
|  |  | 1. Brominated vegetable oil (BVO) floats on top of water. |
|  |  | 1. Citrus oil molecules dissolve in both water and BVO. |
|  |  | 1. Bromine is colorless and odorless. |
|  |  | 1. Studies on lab rats show that bromine can build up in fatty tissues and disrupt the functioning of hormones. |
|  |  | 1. BVO is found in citrus-flavored soft drinks and sports drinks. |
|  |  | 1. BVO is approved for use in the European Union and Japan. |
|  |  | 1. The U. S. Food and Drug Administration (FDA) bases the acceptable level of BVO in food on studies done in the 1990s. |
|  |  | 1. Pepsi has replaced BVO in its soft drinks with an emulsifier that has FDA approval. |
|  |  | 1. A college student who was rushed to the hospital with tremors and skin lesions (probably caused by drinking too much soda) has fully recovered. |

## Shampoo: From Lab to Shower

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

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. The average person’s head produces about 2 grams (the weight of 2 paper clips) of sebum per day. |
|  |  | 1. Many ingredients in shampoo reduce the surface tension of water. |
|  |  | 1. Surfactants are nonpolar molecules. |
|  |  | 1. Water molecules are polar, while oil molecules are nonpolar. |
|  |  | 1. Polar molecules have partial positive and negative charges. |
|  |  | 1. Surfactant molecules surround oil molecules to form a molecular cluster that can be rinsed away. |
|  |  | 1. The most abundant ingredient in all shampoos is water. |
|  |  | 1. Conditioning molecules are rinsed away when you rinse your hair. |
|  |  | 1. Some conditioning molecules can irritate the eyes. |
|  |  | 1. Shampoo formulations are extremely different for different shampoos. |

Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. 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 articles. The use of bullets helps them do this. If you use these reading strategies 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 |

***Teaching Strategies:***

1. Links to **Common Core Standards for writing**: Ask students to choose one of the articles about performance-enhancing drugs or BVO in this issue to explain the information to a person who has not taken chemistry. Students should provide evidence from the article or other references to support reasons why use of PEDs and/or BVO may be dangerous, especially to teenagers.
2. **Vocabulary** and **concepts** that are reinforced in this issue:

* Carbohydrates
* Equilibrium
* Structural formulas
* Emulsifier
* Polarity
* Surfactant
* Surface tension

1. 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 Sweet Science of Candymaking

**Directions**: As you read, complete the graphic organizer below to analyze the important chemistry concepts and processes involved in making candy.

|  |  |  |
| --- | --- | --- |
| **Chemistry Concept or Process** | **Example from the article** | **Drawing illustrating concept or process** |
| **Intermolecular force** |  |  |
| **Dissolving** |  |  |
| **Dynamic equilibrium** |  |  |
| **Le Chatelier’s Principle** |  |  |
| **Seed crystal** |  |  |
| **Amorphous structure** |  |  |

## Performance-Enhancing Drugs: Is Winning Everything?

**Directions**: As you read the article, complete the graphic organizer below to compare different chemicals found in Performance-Enhancing Drugs (PEDs).

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Testosterone** | **Methenolone** | **Erythropoietin (EPO)** |
| **Type of chemical** |  |  |  |
| **Elements in the compound** |  |  |  |
| **Describe structure in words** |  |  |  |
| **Why it is used** |  |  |  |
| **How it is used** |  |  |  |
| **Famous athlete use** |  |  |  |
| **How it works** |  |  |  |
| **Problems if used by teenagers** |  |  |  |

## The Starting Line of a Drug-Free Athlete

**Directions:** As you read the article, complete the graphic organizer below to compare the different aspects of the ATLAS/ATHENA program.

|  |  |
| --- | --- |
| **ATLAS** | **ATHENA** |
|  |  |
|  |  |
|  |  |
| **Similarities (List at least 6.)** | |

## Do You Know about BVO?

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

|  |  |
| --- | --- |
| **What is it?** |  |
| **Who uses it?** |  |
| **Where is it found?** |  |
| **Why is it used?** |  |
| **What elements are in it?** |  |
| **What are some better alternatives?** |  |
| **When was it approved for use in the U. S.?** |  |
| **What are some possible hazards of using it?** |  |

## Shampoo: From Lab to Shower

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

How they work

Definition

Non-Examples

Examples

# The Sweet Science of Candymaking

## Background Information (teacher information)

It seems just a bit odd that this article on candy and sugar is juxtaposed against the article about “toxic sugar” on the preceding page of this issue. But in reality, only a small fraction of the sugar we consume comes from candy. A far larger portion of the sugar in our diet comes from soft drinks—to the tune of 10–12 teaspoons per 12-oz. can! And sugar is also added to many other foods we eat, like breads, sauces, dairy products and alcoholic beverages. Research shows that the average American gets 33% of that 40 kg (88 pounds) of added sugar from beverages containing high fructose corn syrup. And candy comes in as a close second at about 27%. So, we probably should be prudent in our consumption of candy. (But how can we, when it’s so yummy?).

**More on the history of candy**

The earliest forms of candy were honey or, later, sugar, either alone or coating other materials, like fruit or nuts. The origin of rock candy, pure sugar, traces back to India and Iran between the 6th and 4th centuries BCE. It was then used as a medicine and as a preservative for some foods. In 1596 in *Henry IV*, Shakespeare referred to its therapeutic value to soothe the throat of the long-winded talker. By the mid-1700s rock candy had attained its present use as a candy.

In America, almost all of candies were handmade in the home. A few commercial candies were available in the time of the American Revolution, including sugar plums (remember Clement Moore’s “A Visit from St. Nicholas”?), (hard) sugar candy, and sugar ornaments, but most of these were imported from Europe and very expensive.

Sugar-based candies were very expensive for several reasons: growing sugar cane or sugar beets and the subsequent processing into sugar were both very time- and labor-intensive undertakings, making sugar a very expensive commodity. In early America, sugar plantations were a major part of our economy.

In the seventeenth and eighteenth centuries, sugar plantations were sources of immense wealth, and whoever controlled the sugar trade also wielded substantial political and economic power. Sugar was dear, and sweet foods costly. Powerful hosts would display their wealth at banquets with sumptuous sugar-spun centerpieces, a form of conspicuous consumption made all the more excessive by the fact that the sugar would go to waste. As production became more mechanized in the nineteenth century, the price of sugar fell. By the second half of the nineteenth century, sugar was both cheap and widely available.

(Kawash, S. *Candy: A Century of Panic and Pleasure*; Faber and Faber, Inc.: New York, NY, 2013, p 17)

By the mid-1880s, candy made commercially (still made by hand) in the U.S. consisted of stick candies and taffies. Druggists even made their own candy, since they were already in the business of making sugar lozenges for medicinal uses. But outside the cities, poorer rural Americans had to settle for homemade molasses or maple sugar candies.

But candy production really took off with the industrial revolution, when mechanized steam-driven processes transformed the sugar refining process, and the candy making process could be scaled up by using other steam-driven machines to produce candy in huge amounts in factories.

The numbers tell the story. The value of manufactured candy leapt from $3 million in 1850 to over $60 million in 1900. By 1948, the equivalent figure topped $1 billion for the first time. The per capita story is even more telling: from two pounds per capita in 1900, to fifteen pounds in 1923, to more than twenty pounds in candy’s banner year, 1944 (although fully one-quarter of this production was sequestered for military use, leaving many civilians frustrated in a nation awash in product). … From an occasional luxury to a staple of the American diet, candy has come a long way. (ibid., 29)

As mechanized production reduced the time needed to make the candy product, production was multiplied manifold; and since the level of skill needed to work the machines was far less than that needed to produce the candy by hand, labor costs were greatly reduced. Greater production and lower labor costs resulted in such reductions in price for candy that now even the average citizen could now afford candy.

In an era when candy was cheap, people began to view it as a food, not just a luxury. Scientists of the late 1800s such as Dr. Wilbur Atwater studied human metabolism and caloric values of foods. Atwater established calorie requirements for the average worker of the time, and concluded that workers needed 3500 calories a day, coming from protein, fat and carbohydrates. Expressed this way, it almost seemed that it didn’t matter what the source of those calories was. They concluded that, since candy contained so many calories, it must be “a nourishing and sustaining food…” according to Professor John C. Olsen of the Brooklyn Polytechnic Institute. He actually concluded that chocolate creams and peanuts were equally good as mainstays of any diet—better than eggs! (ibid., 98)

Of course, this view changed greatly over the years as scientists learned more about nutrition and the actual metabolic needs of the human body, but in those days, there was more concern for the on-average, under-nourished person than the present-day over-nourished (think obese) person.

As it became known that candy wasn’t necessarily a good food, it became more and more important for candy manufacturers such as Hershey and Mars to advertise, in order to entice people to eat their products.

Early on in the1900s, athletes were used by advertisers (probably no surprise there) as examples of candy-eaters who absolutely needed the energy contained in their candy bars. And if athletes needed them, who could doubt that the average consumer needed them, too? New methods of packaging and candy wrapping also contributed to the overwhelming acceptance of candy by the buying public. Other advertising campaigns over the years, along with innovations that kept producing new and enticing types of candies kept candy front and foremost in the minds of the American consuming public.

**More on** **heating sugar to make various types of candy**

The Exploratorium in San Francisco (via their Web site) offers this information about heating sugar to make candy:

**What happens when you heat a sugar solution?**

When you add sugar to water, the sugar crystals dissolve and the sugar goes into solution. But you can’t dissolve an infinite amount of sugar into a fixed volume of water. When as much sugar has been dissolved into a solution as possible, the solution is said to be saturated.

The saturation point is different at different temperatures. The higher the temperature, the more sugar that can be held in solution.

When you cook up a batch of candy, you cook sugar, water, and various other ingredients to extremely high temperatures. At these high temperatures, the sugar remains in solution, even though much of the water has boiled away. But when the candy is through cooking and begins to cool, there is more sugar in solution than is normally possible. The solution is said to be supersaturated with sugar.

Supersaturation is an unstable state. The sugar molecules will begin to crystallize back into a solid at the least provocation. Stirring or jostling of any kind can cause the sugar to begin crystallizing.

**Why are crystals undesirable in some candy recipes—and how do you stop them from forming?**

The fact that sugar solidifies into crystals is extremely important in candy making. There are basically two categories of candies—*crystalline* (candies which contain crystals in their finished form, such as fudge and fondant), and *noncrystalline*, or *amorphous* (candies which do not contain crystals, such as lollipops, taffy, and caramels). Recipe ingredients and procedures for noncrystalline candies are specifically designed to prevent the formation of sugar crystals, because they give the resulting candy a grainy texture.

One way to prevent the crystallization of sucrose in candy is to make sure that there are other types of sugar—usually, fructose and glucose—to get in the way. Large crystals of sucrose have a harder time forming when molecules of fructose and glucose are around. Crystals form something like Legos locking together, except that instead of Lego pieces, there are molecules. If some of the molecules are a different size and shape, they won’t fit together, and a crystal doesn’t form.

A simple way to get other types of sugar into the mix is to "invert" the sucrose (the basic white sugar you know well) by adding an acid to the recipe. Acids such as lemon juice or cream of tartar cause sucrose to break up (or invert) into its two simpler components, fructose and glucose. Another way is to add a nonsucrose sugar, such as corn syrup, which is mainly glucose. Some lollipop recipes use as much as 50% corn syrup; this is to prevent sugar crystals from ruining the texture.

Fats in candy serve a similar purpose. Fatty ingredients such as butter help interfere with crystallization—again, by getting in the way of the sucrose molecules that are trying to lock together into crystals. Toffee owes its smooth texture and easy breakability to an absence of sugar crystals, thanks to a large amount of butter in the mix.

(<https://www.exploratorium.edu/cooking/candy/sugar.html>)

The following sequence of steps describes how to use a candy thermometer to demonstrate the various stages of sugar solution as it is heated from boiling all the way up to burning:

1. Pour 2 parts of water in a saucepan and set it on the stove. Attach a candy thermometer to the inside of the saucepan. Turn the heat to high heat.
2. Add 1 part of sugar and stir until dissolved. Make sure the sugar is dissolved before the mixture starts boiling. Scrape the bottom and sides of the pan while you are stirring.
3. Let the sugar water mixture boil for 10 minutes. Keep an eye on the temperature on the thermometer. If the temperature has reached 230 to 238 degrees Fahrenheit, it is in the thread stage. The sugar will form a fine thread when a teaspoonful of the mixture is dropped in ice cold water.
4. Continue boiling the sugar until the thermometer reads 238 to 245 F. This is the soft ball sage. In this stage, the sugar can be rolled in to a ball after being dropped in a dish of ice water. The ball will be soft and easily moldable.
5. Boil the sugar for a little bit longer. When the temperature reaches 245 to 250 F, it has entered the firm ball stage. You will be able to roll the cooled sugar in to a ball. The ball will flatten when you press it, but it will be firm.
6. Let the sugar boil to 250 to 265 F, which is the hard ball stage. At this stage, when you drop a ball of the mixture into ice water, it will form a ball that will be hard. The ball will not give when pressed.
7. Allow the sugar to heat to 270 to 290 F, which is the hard crack stage. When you stretch the cooled ball from the ice water, it will form threads that will crack.
8. Boil your sugar until it reaches 305 to 325 F. At this temperature your sugar will be in the hard crack stage, where it forms a hard ball when cooled that separates into threads.
9. Make caramel by boiling your sugar to the light caramel stage. The sugar and water has reached this stage when your sugar thermometer reads 345 F.

After the sugar reaches 410 F, it will turn black and start to burn.

(<http://www.ehow.com/how_5805661_boil-water-sugar.html>)

This Web site shows pictures of each of the stages of heating the sugar solution: <http://candy.about.com/od/candybasics/ss/candytempsbs.htm>.

And here is essentially the same information in table format:

|  |  |  |
| --- | --- | --- |
| **TEMPERATURE - SYRUP'S BOILING POINT AT SEA LEVEL** Measure with a Candy Thermometer | **CANDY** | **COLD WATER - SYRUP'S CONCENTRATION TEST** |
| **Water boils at Sea Level 212 degrees F** | Water, [**Simple sugar syrups**](http://baking911.com/candy/syrups/basic-simple-sugar-syrup-flavor-variations) | **NOTE - For Higher Altitudes:** There are modifications that need to be made to candy recipes. For every 1,000 feet/300 meters above sea level, subtract 2 degrees F. For degrees C, for each 900 feet of elevation, subtract 1 degree C. |
| **Thread Stage** 215° F–234° F /101° C–112° C sugar concentration: 80% | Sugar syrup, fruit liqueur and [**some icings**](http://baking911.com/learn/baked-goods/frosting-icing-etc) | Thread: At this relatively low temperature, there is still a lot of water left in the syrup. The liquid sugar may be pulled into brittle threads between the fingers. Or, take a small amount of the syrup onto a spoon, and drop it from about 2-inches above the pot. Let it drip into the pan. If it spins a long thread, like a spider web, it's done. |
|  | Jelly, candy, fruit liqueur making and [**some icings**](http://baking911.com/learn/baked-goods/frosting-icing-etc) | Pearl: 220 - 222 degrees F - The thread formed by pulling the liquid sugar may be stretched. When a cool metal spoon is dipped into the syrup and then raised, the syrup runs off in drops which merge to form a sheet. |
|  | Delicate sugar candy and syrup | Blow or Soufflé: 230 - 235 degrees F - Boiling sugar creates small bubbles resembling snowflakes. The syrup spins a 2-inch thread when dropped from a spoon. |
| **Soft-Ball Stage** 234° F–240° F /112° C–115° C sugar concentration: 85% | [**Fudge**](http://baking911.com/learn/baked-goods/candy/types/fudge), [**Fondant**](http://baking911.com/learn/baked-goods/candy/types/fondant), [**pralines**](http://baking911.com/learn/baked-goods/candy/types/pralines), pâte â bombe or [**Italian meringue**](http://baking911.com/learn/baked-goods/frosting-icing-etc), peppermint creams and [**classic buttercreams**](http://baking911.com/learn/baked-goods/frosting-icing-etc) | Soft ball: A small amount of syrup dropped into chilled water forms a soft, flexible ball, but flattens like a pancake after a few moments in your hand. |
| **Firm-Ball Stage** 242° F–248° F /116° C–120° C sugar concentration: 87% | [**Caramel candies**](http://baking911.com/learn/baked-goods/candy/types/caramel) | Firm ball: Forms a firm ball that will not flatten when removed from water, but remains malleable and will flatten when squeezed. |
| **Hard-Ball Stage** 250° F–268° F /121° C–131° C sugar concentration: 92% | [**Nougat**](http://baking911.com/learn/baked-goods/candy/types/nougat), [**marshmallows**](http://baking911.com/learn/baked-goods/candy/types/marshmallows), [**toffee**](http://baking911.com/learn/baked-goods/candy/types/toffee), [**gummies**](http://baking911.com/learn/baked-goods/candy/types/gummy-candies), [**divinity**](http://baking911.com/learn/baked-goods/candy/types/divinity), and [**rock candy**](http://baking911.com/learn/baked-goods/candy/types/rock-candy) | Hard ball: At this stage, the syrup will form thick, "ropy" threads as it drips from the spoon. The sugar concentration is rather high now, which means there’s less and less moisture in the sugar syrup. Syrup dropped into ice water may be formed into a hard ball which holds its shape on removal. The ball will be hard, but you can still change its shape by squashing it. |
| **Soft-Crack Stage** 270° F–290° F /132° C–143° C sugar concentration: 95% | Taffy, [**Butterscotch,**](http://baking911.com/learn/baked-goods/candy/types/butterscotch) [**Candy apples**](http://baking911.com/candy/caramel-and-candy-apples/candy-apples) | Soft Crack: As the syrup reached soft-crack stage, the bubbles on top will become smaller, thicker, and closer together. At this stage, the moisture content is low. Syrup dropped into ice water separates into hard but pliable threads. They will bend slightly before breaking. |
| **Hard-Crack Stage** 300° F–310° F /148° C–154° C sugar concentration: 99% | [**Brittles**](http://baking911.com/learn/baked-goods/candy/types/brittle), [**hard candy(lollipops)**](http://baking911.com/learn/baked-goods/candy/types/hard-candy) | Hard Crack: The hard-crack stage is the highest temperature you are likely to see specified in a candy recipe. At these temperatures, there is almost no water left in the syrup. Syrup dropped into ice water separates into hard, brittle threads that break when bent. |
| **CARAMELIZING** **SUGAR  320 ° F + / 160 ° C +** Sugar (sucrose) begins to melt around 320° F and caramelize around 340° F. | [**Thermal Decomposition**](http://baking911.com/quick-guide/how-baking-works/sweeteners) | If you heat a sugar syrup to temperatures higher than any of the candy stages, you will be on your way to creating caramelized sugar (the brown liquid stage)—a rich addition to many desserts. |
| 330 - 360° F / 165 - 182° C Above 330° F, the sugar syrup is more than 99% sucrose. | From [**flan**](http://baking911.com/learn/baked-goods/custard/types/flan) to caramel cages, etc. | Caramel: Syrup goes from clear to brown as its temperature rises. It no longer boils, but begins to break down and caramelize. |
| 340° F /171° C | Light caramel for syrups, color and flavor | Caramel - Light Brown: The liquefied sugar turns brown. Now the liquefied sugar turns brown in color due to caramelization. The sugar is beginning to break down and form many complex compounds that contribute to a richer flavor.  Caramelized sugar is used for [**flan syrup**](http://baking911.com/learn/baked-goods/custard/types/flan), dessert decorations and can also be used to give a candy coating to nuts. |
| 355 - 360° F /179–182° C | Spun sugar, sugar cages | Caramel - Medium Brown: The liquefied sugar darkens |
| 375 - 380° F /190–193° C | Coloring agent for sauces. | Caramel - Dark Brown: The liquefied sugar darkens further. |
| 410° F /210° C | None | Black Jack: The liquefied sugar turns black and then decomposes. |

(<http://baking911.com/quick-guide/how-to-az/candy-sugar-syrup-temperature-chart>)

Candies aren’t the only substances that change properties with sugar concentration. You will sometimes find the term “degrees brix” in literature describing the sugar content of wines (from the sugar in grapes) and maple syrup (from the sugar in maple tree sap).

**Degrees Brix** (symbol °Bx) is the [sugar](http://en.wikipedia.org/wiki/Sugar) content of an aqueous solution. One degree Brix is 1 gram of [sucrose](http://en.wikipedia.org/wiki/Sucrose) in 100 grams of solution and represents the strength of the solution as [percentage by mass](http://en.wikipedia.org/wiki/Percentage_by_mass). If the solution contains dissolved solids other than pure sucrose, then the °Bx only approximates the dissolved solid content. The °Bx is traditionally used in the [wine](http://en.wikipedia.org/wiki/Wine), [sugar](http://en.wikipedia.org/wiki/Sugar), [carbonated beverage](http://en.wikipedia.org/wiki/Carbonated_beverage), [fruit juice](http://en.wikipedia.org/wiki/Fruit_juice), and [honey](http://en.wikipedia.org/wiki/Honey) industries.

(<http://en.wikipedia.org/wiki/Brix>)

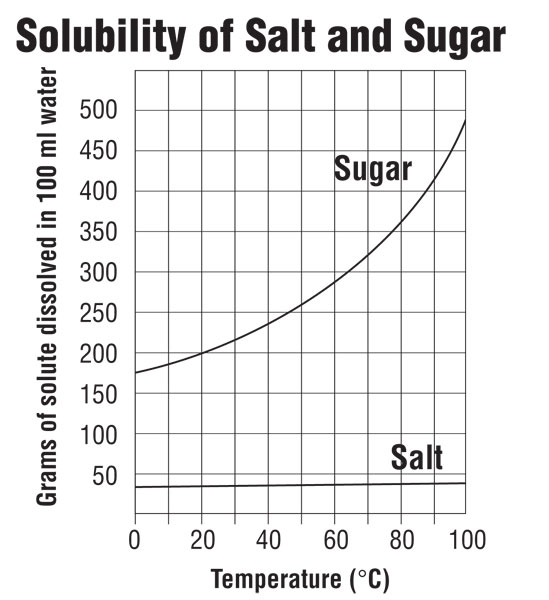
Maple syrup as it emerges from maple trees is rather runny (not very viscous). To produce a good maple syrup, the tree sap must be heated to boiling to remove water, until the syrup reaches a standard density of between 66.5 and 66.7 oBx. This means that the syrup contains between 66.5 and 66.7 grams of maple sugar for every 100 grams of solution, or 66.5–66.7% sugar by mass. Contrast this with the 3–6% sugar content of the original tree sap. The concentration is measured using a hydrometer.

The standard density provides a boiling point 7–7.1 oF higher than the boiling temperature of water. It would be interesting to have students calculate the molal boiling point elevation of a solution of maple syrup (essentially sucrose) that is 66.5% or so content by mass and compare the result of that calculation to the temperature provided above. They could then hypothesize why their value is different than the standard value.

A lower density results in a syrup that is too runny, while one above this standard density will be too thick and runs the risk of forming sugar crystals during storage. (It takes about 36 gallons of tree sap to produce one gallon of maple syrup.)

(from About food.com: <http://homecooking.about.com/od/specificfoo1/a/makemaplesyrup.htm?utm_term=brix%20sugar&utm_content=p1-main-2-title&utm_medium=sem&utm_source=msn&utm_campaign=adid-1733ff32-2bc7-4b1f-9bbe-7076918b4aba-0-ab_msb_ocode-5995&ad=semD&an=msn_s&am=broad&q=brix%20sugar&dqi=brix%2520sugar&o=5995&l=sem&qsrc=999&askid=1733ff32-2bc7-4b1f-9bbe-7076918b4aba-0-ab_msb>)

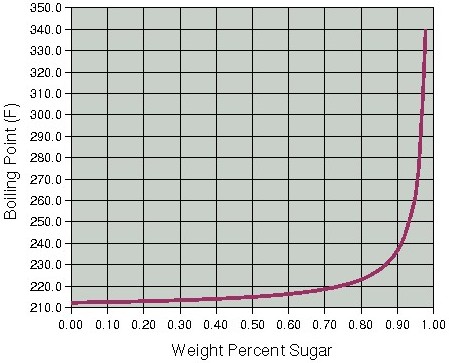
So, why DOES a sugar solution go through all these stages when heated? It all comes down to the bonding within the solution. When the sugar/water solution is dilute, the primary bonding that occurs is between many water and few sugar molecules, or between the plentiful water molecules; both of these bonds are primarily hydrogen bonding, which is relatively weak. This is reflected by the boiling point being very close to that of pure water. But as the solution is heated and water is driven off, there are fewer and fewer hydrogen bonds between water and water or water and sugar, and more and more covalent bonds between sugar molecules, until primarily covalent bonding between sugar molecules becomes more prevalent, resulting in an increase in the boiling point of the mixture.



*(*[*http://www.middleschoolchemistry.com/img/content/multimedia/chapter\_5/lesson\_6/solubility\_curve\_big.jpg*](http://www.middleschoolchemistry.com/img/content/multimedia/chapter_5/lesson_6/solubility_curve_big.jpg)*)*

This solubility chart for sugar and salt (at the right, above), from the American Chemical Society Middle School Chemistry curriculum shows how sugar’s solubility increases with increased temperature.

This graph (right) shows the boiling temperature of a sugar/water solution varying with relative concentration of sugar in the solution (rather than just amount of sugar, as in the preceding graph). The temperature axis begins approximately at the boiling point of water. Note on this graph, how the boiling point of the solution increases drastically as the concentration approaches 100% sugar (all the water is being boiled off). As a result of the removal of water, the covalent bonding between sugar molecules is much more prevalent in the concentrated solution than the predominantly hydrogen-bonding between water molecules and sugar molecules in the less concentrated solution. That means the sugar molecules, with the relatively few water molecules still remaining in solution are held much more tightly together in the concentrate,   
making it more difficult to change the phase of this mixture, raising the boiling point. Eventually the sugar concentration approaches/reaches 100% and at that point, the sugar will caramelize or even char, rather than boil.



*(*[*http://www.personal.kent.edu/~cearley/ChemWrld/sugarwater/sugar.htm*](http://www.personal.kent.edu/~cearley/ChemWrld/sugarwater/sugar.htm)*)*

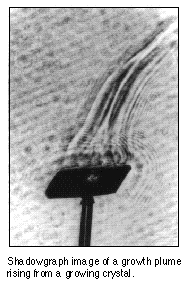
Each change in the percentage of sugar and water in the mixture results in a change in the properties of the mixture, accounting for the various stages in heating the sugar solution. Note the percentages of sugar in the solutions at the various stages of heating the sugar solution, from the table in the “More on heating sugar …” section above.

**More on recent research on sugar melting**

Until recently (2011) scientists believed that sugar melted, but everyone agreed that it was difficult to determine its melting temperature and that it varied widely, apparently due to impurities and such. But recent research seems to prove otherwise. Researcher Shelly Schmidt, University of Illinois professor of food chemistry has discovered that “Sugar crystals do not melt, but instead decompose in a heat sensitive reaction termed ‘apparent melting’.” The researchers now believe that the “… the loss of crystalline structure in sucrose, glucose, and fructose has been shown to be due to the kinetic process of thermal decomposition … rather than thermodynamic melting.” The decomposition process under controlled temperature conditions has been given the term “apparent melting”.

The researchers’ curiosity was aroused when it was determined that new compounds were discovered at the melting temperature. Typically when a substance melts, it retains its chemical identity, but that is not what was happening with sugar. The new substances formed indicated that chemical reactions were happening at those temperatures. And different substances were produced depending on the rate of heating. The importance of this finding is that food chemists will now be able to better control flavors in sugar at high temperature, to better avoid bitter tastes that come from the decomposition process, by controlling the rate of heating. ([http://www.foodnavigator.com/Science-Nutrition/Sugar-doesn-t-melt-it-decomposes-say-researchers](http://www.foodnavigator.com/Science-Nutrition/Sugar-doesn-t-melt-it-decomposes-say-researchers?utm_source=copyright&utm_medium=OnSite&utm_campaign=copyright))

**More on crystals, crystallizing and dissolving**

When sugar crystals grow from a solution, if you look very closely you can see what are called *growth plumes* rising from the crystal. These are the result of less concentrated solution forming in the region where crystallization is taking place, due to the sugar molecules leaving the solution to precipitate onto the existing crystal. This less concentrated solution is less dense than the surrounding solution and, hence, is buoyed up by the more dense solution. This causes what is also known as the schlieiren effect, when two different density solutions interact and refract light differently.

A rising growth plume (schlieiren up) indicates crystal growth; conversely, a sinking plume (schlieiren down) indicates that the existing crystal is actually dissolving into the solution, resulting in solution right around the crystal that is denser than its surroundings, due to greater concentration. This denser liquid falls through the less dense solution. A student experiment from the NASA Quest Web site that allows students to view these plumes can be found here: <http://quest.arc.nasa.gov/space/teachers/mg/14crystal-growth.html>. (The shadowgraph above comes from the same site.)

The importance of these growth plumes is that they can indicate the condition of the growing medium. When you try to grow crystals, you typically need to have a supersaturated solution, or at minimum, a saturated solution. When a seed crystal is placed in this medium, molecules (or ions) in the solution will crystallize out on that crystal. But this will only happen if the solution is saturated. If the concentration is such that it is unsaturated, then the seed crystal will begin to dissolve as the solid tries to saturate the solution.

So the crystal grower can observe quickly whether the plumes are rising or sinking. If they rise, that means the crystal is growing and the growth medium is saturated; if the plumes sink, that means the crystal is actually dissolving into the growth solution, and the solution is therefore unsaturated. To continue growing crystals from the solution, the experimenter will need to either add more solute to increase the concentration to the saturation point, or else heat the solution to drive off water, thereby increasing the concentration to the saturation point by lowering the volume of solvent.

## Connections to Chemistry Concepts (for correlation to course curriculum)

1. **Solubility**—The solubility of sugar and how that solubility changes with temperature determines how much you must add and how hot you must heat it to get it all to dissolve
2. **Intermolecular forces**—Sugar crystals are pulled apart by the formation of hydrogen bonds between the sugar and water molecules.
3. **Equilibrium**—Equilibrium is maintained in a saturated sugar solution as molecules dissolve and crystallize at equal rates.
4. **Le Chatelier’s principle**—Heating the sugar mixture to begin making rock candy upsets the equilibrium of the saturated solution, forcing more molecules of sugar to dissolve, breaking bonds and thereby absorbing energy to reduce the stress of increased temperature.
5. **Rate of reaction**—Heating the sugar mixture increases the rate of dissolving.
6. **Kinetic molecular theory—**Crystal size is dependent on the amount of time in the growing medium, due to the need for molecules dissolved in solution to move around in order to be in contact with the seed crystal.
7. **Organic chemistry**—Sugar is a carbohydrates, a disaccharide, composed of two monosaccharides.
8. **Bond breaking and forming**—Dissolving is a bond-breaking process, while crystallization is a bond-forming process.
9. **Thermochemistry**—Various temperatures are responsible for the varied properties of the sugar/water mixture in candy making due, at least in part, to bonds breaking and forming.

## Possible Student Misconceptions (to aid teacher in addressing misconceptions)

1. **“Rock candy can be clear, so it must be a glass, like cotton candy.”** *[Start explanation here—in italics.]*
2. **“Rock candy is the only kind of crystal I can easily grow.”** *Actually, it may be the hardest to grow (in a large crystal, that is). Although crystals grow easily, they are usually very small and randomly grown. Other substances one can use to grow larger, individual crystals are alum (pickling material from the grocery store), magnesium sulfate (Epsom salts from the drug store) and copper sulfate (root killer in the hardware store).*
3. **“Sugar melts with heat.”** *Actually, this is probably a teacher misconception, also—unless you’ve read the real story in the background section, “More on recent research on sugar”, above. Short version of the story: sugar doesn’t melt, it decomposes.*
4. **“Once you’ve reached a saturated solution, nothing changes.”** *While this may be true macroscopically, at the microscopic (molecular) level, all the molecules are constantly moving and the dissolving and crystallizing reactions are both still happening. The reason they don’t translate into a visible change is because the rates of the two reverse processes are equal and no net change occurs.*

## Anticipating Student Questions (answers to questions students might ask in class)

1. **“When you boil the sugar/water mixture to make rock candy, does the sugar boil away?”** *When you boil the sugar/water mixture, it is the water that is boiling, not the sucrose. Water’s boiling temperature is well below the melting temperature of sucrose. Actually, sucrose decomposes back into glucose and fructose, rather than melting, at   
   186 oC. After the solution boils for a while, the solution’s bubbles increase in viscosity (thickness, or resistance to flow) because they are coming from, and must bubble up through, a very viscous solution of sugar and water. In addition to dissolving more sugar at higher temperature, the boiling process here also serves to eliminate much water from the solution, resulting in the sugar being much more concentrated in the solution.*
2. **“Does sugar burn?”** *If you heat sugar solution to high enough temperatures, the sugar will caramelize, or turn brown, beginning to char, but it won’t burn with a flame. If one tries to light pure sugar—say, a sugar cube, or a pile of sugar—with a match, it will not burn, unless coated with ash. (See In-Class Activities section for this activity.) Sugar CAN burn, however, if it is in powdered (dust) form. Then air can surround each small particle of sugar and keep the burning process going. (See References section below for a reference to a previous ChemMatters article on this phenomenon.)*

## In-class Activities (lesson ideas, including labs & demonstrations)

Candy seems to be the ideal substance around which to build student activities!

The first series of experiments that follow (# 1–5) all involve making various types of candy:

1. The Serendip Studio Web site (from Bryn Mawr College, Bryn Mawr, PA) provides this series of four experiments by teacher Robert Farber for students to make rock candy and experiment with the effects of temperature and additives on the candy’s crystal size. The experiments are fairly straight-forward, with objectives provided, but they could be made more inquiry-based with modifications to the procedure to give students more control over the procedure. There is no teacher version on the site. (<http://serendip.brynmawr.edu/sci_edu/farber/pdf/candy.pdf>) Here’s a Word document of the same experiment, in case you want to easily edit it: <http://serendip.brynmawr.edu/sci_edu/farber/word/CANDY-r.doc>.
2. Here is an experiment, designed for “Advanced Chemistry Students” to construct “Variegated Disaccharide ‘J’ Tubes” (candy canes). The directions are very “scientific”, but it is a “cookbook” lab. No teacher version was found online. (<http://www.hschem.org/Laboratory/ConstructionofVariegatedDisaccharide.pdf>)
3. Here are two experiments to make peanut brittle.
4. Here’s another scientific-sounding experiment: “Thermal Degradation of Mixed Saccharides with Protein Inclusions” (peanut brittle): <http://www.chymist.com/peanut%20brittle.pdf>. This one, from Dave Katz, contains the student version and a page of teacher notes.
5. Peanut brittle uses corn syrup (glucose solution) as an ingredient to help prevent crystals from forming in the candy. The *ChemMatters* article “Peanut Brittle” includes a one-page student lab recipe (*ChemMatters* **1991,** *9* (4), pp 4–7).
6. Students could even make chocolate-covered cherries, which use the action of the enzyme invertase (available from candy-making suppliers) to create the liquid center. The enzyme catalyzes the breakdown of sucrose into fructose and glucose. Recipes are available online; one example is <http://www.nydailynews.com/lifestyle/food/2010/02/10/2010-02-10_for_valentines_day_homemade_chocolates_that_are_guaranteed_to_melt_hearts.html>. Note that this is probably a recipe for more experienced candy makers and may not fit a lab setting. It might more conveniently be done at home.
7. The pdf document “Learning the Principles of Glass Science and Technology from Candy Making” describes a series of experiments involving candy making, aimed at a college- or second-year-level chemistry course: <http://www.lehigh.edu/~inmatsci/faculty/jain/candy_making.pdf>. It contains teacher material at the end.

Dissolving of sugar in water and re-crystallizing it from a supersaturated solution is the topic of the following group of activities (# 6–11):

1. This short (4:19) video clip by Richard Hartel, Ph.D., professor of food engineering at the University of Wisconsin-Madison could be used in a class discussion of how candy is made. The video shows how hard candy (“sugar glass” in the trade) is made: <https://www.youtube.com/watch?feature=player_embedded&v=VY8q0hN6KwA>. The video discusses the various stages (at specific temperatures) of candymaking.
2. This computer simulation from PhET from the University of Colorado, Boulder, shows what happens when salt and sugar dissolve (separately or together). The process of dissolving can be viewed at the macro- or micro-level, with or without the solvent (water) showing. (<http://phet.colorado.edu/en/simulation/sugar-and-salt-solutions>) This is a rather simplistic simulation, but it may help students to visualize what happens at the microscopic level, and you can use it to differentiate between ions (salt) and molecules (sugar), electrolytes and non-electrolytes. A series of teacher/student activities on the dissolving of sugar and salt accompanies this simulation. (<http://phet.colorado.edu/en/search?q=sugar+dissolv>)
3. Another simulation from PhET shows at the molecular level when a salt dissolves in water: <http://phet.colorado.edu/en/simulation/soluble-salts>. This simulation gives students opportunity to alter the variables of volume of solvent and amount of solute, to actually calculate Ksp, and it provides other salts with which to experiment.
4. The American Chemical Society has a Web site, *Middle School Chemistry: Big Ideas about the Very Small* at <http://www.middleschoolchemistry.com/>. This site contains their book that provides lesson plans and multi-media about these six chemistry topics: 1) Matter: Solids, Liquids and Gases; 2) Changes of State; 3) Density; 4) The Periodic Table and Bonding; 5) The Water Molecule and Dissolving; and 6) Chemical Change. The part of the site that is of primary concern for this Teacher’s Guide is chapter 5, The Water Molecule and Dissolving. It describes the polar nature of water, and contains two separate sections that explain the dissolving of a) salt and b) sugar, explaining ionic and molecular bonding. The lessons are based on the 5E model of learning (engage, explore, explain, evaluate, extend/elaborate) and, although geared for middle school, these lessons and multi-media can be used in introductory chemistry classes and adapted to high school level classes (e.g., while providing useful student activities and handouts [including graphics], the sections on the dissolving of sugar and salt in water discuss the polarity of water, salt and sugar, make no mention of polar covalent bonds or hydrogen bonding, but the high school teacher can bring both of these concepts into the discussion in a high school classroom).
5. Since the preparation of rock candy uses the idea of increased solubility (of sugar) with increased temperature, you might want to use an activity such as this one to show how solubility does, indeed, vary with temperature for most solids. This activity uses either KClO3 or KNO3 to determine the solubility of the solid at various temperatures, and from that data, students can prepare a solubility chart. (<http://www.chymist.com/Solubility%20salt.pdf>)
6. On the topic of crystal-growing, this experiment from NASA discusses “growth plumes” in a crystal-growing solution, and what they indicate in terms of crystal growth. Using alum (aluminum potassium sulfate) students grow crystals and project the image of the growth cell with a projector. A shadowgraph shows convection plumes rising from the seed crystal, indicating crystal growth. If the plumes were sinking, that would indicate crystal shrinkage. (<http://quest.arc.nasa.gov/space/teachers/mg/14crystal-growth.html>)

This PowerPoint set of slides provides a very nice close-up photograph from McGraw-Hill, showing a sugar cube dissolving. It illustrates the sinking plumes that accompany the dissolving process, slide 8: <http://www.umsl.edu/~chickosj/chem11/Lecture/Lecture13.ppt>.

Here are other activities that use candy to teach other chemistry concepts:

1. Use this activity to have students determine the amount of CO2 in Pop Rocks®: *ChemMatters* Teacher’s Guide. December 1993. We suggest making it more inquiry based by editing it so that students decide the purpose of the experiment (to find actual amount of CO2, mass ofCO2, weight-percent CO2, etc.) and design the standard method for the whole class to use to do the experiment, so that team results can be compared.
2. The Web site Steve Spangler Science contains three experiments dealing with candy that could be used in the classroom, or as a project for students outside of class. The experiments involve floating/sinking candy bars, growing gummy bears (left to sit in water), and the Mentos/soda geyser. View the brief experiments at <http://www.stevespanglerscience.com/lab/experiments/candy-chemistry-experiments>. Note that the site provides explanations for the results of the experiments (maybe not a good thing for students to see), although it also suggests extensions of the experiments for students to try.
3. These experiments/demonstrations all show the thermal destruction of gummy candies.
4. This high school chemistry demonstration from MIT that shows you how to safely conduct a violent combustion (oxidation-reduction) reaction called “Toasting a Gummy Candy”. Gummy candies are (very carefully) put into a test tube containing hot, molten potassium chlorate; the sugar content combusts VERY exothermically in the presence of the oxygen produced from the heated KClO3. If you do this demonstration, be SURE to follow all safety procedures! (<http://ocw.mit.edu/high-school/chemistry/demonstrations/videos/death-of-a-gummy-bear/gummy_bear.pdf>)
5. If you’d rather SHOW students how it works (with a video), try any of these videos:
6. MIT provides a 6:18 video that shows a professor discussing and doing the demonstration, interrupted by a narrator using a whiteboard to explain the chemistry behind the reaction. (<http://ocw.mit.edu/high-school/chemistry/demonstrations/videos/death-of-a-gummy-bear/>)
7. You can also check out Steve Spangler Science’s “Screaming Gummy Worms” (really, gummy bears) video (2:59) demonstration at <https://www.youtube.com/watch?v=nSYDd3j1Luk&feature=player_embedded>.
8. Or this one, “The Growling Gummy Bear” (6:15), from the Periodic Table of Videos, from the University of Nottingham, UK, which has great photography (a British accent, naturally, from the narrator) and a follow-up at the end that describes the chemistry of the reaction: <https://www.youtube.com/watch?v=mIr4dLGwaVs&feature=player_embedded>.

NOTE: there are LOTS of videos on YouTube showing the gummy bear reaction, but almost all of them have serious safety flaws. (You might also want to find one of these and show it to your class, asking students to point out the safety problems. See Outside-of-Class Activities, below for suggested videos.)

1. Compare the gummy bear reaction with a sugar cube reacting with KClO3 here: <https://www.youtube.com/watch?v=nN8xD_bv2aQ&feature=player_embedded>.
2. Here’s another (6:44) video from the Periodic Table of Videos, from the University of Nottingham, UK, that experiments on Cadbury Crème Eggs in a variety of ways. (<http://www.youtube.com/watch?v=K6GyJBgBk2o>)
3. BEFORE doing the gummy bear demonstration above, you might want to show how difficult it is to ignite a gummy bear with a burner, either as a demonstration, or using a video like this one (1:52; you can show only part of it, as several gummy bears are burned and they all look alike; they just melt, smolder, and char—no open flame on them): <https://www.youtube.com/watch?feature=player_embedded&v=P3p3mrTqrSY>.   
   You can show them that the bears don’t really ignite, they just melt and char. Then ask them to predict what will happen to the bear in the presence of oxygen (from the molten KClO3); and THEN show them the demonstration or one of the videos above. <https://www.youtube.com/watch?feature=player_embedded&v=P3p3mrTqrSY>
4. An old demonstration related to burning sugar involves trying to burn a sugar cube with a match or burner. It merely melts (or chars, if you use a hot flame). Then dip a sugar cube in wood ashes of some sort (used to be cigarette ash, but that may be hard to obtain now). Now the cube will ignite, although it burns slowly, vis a vis the gummy bear /KClO3 demo. (See 0:58 video at <https://www.youtube.com/watch?v=1PsuRmFhN8c>.) It is believed by some (most) that the ash acts as a catalyst in the reaction, although that may not be the whole story; see the discussion at this Google Groups site: <https://groups.google.com/forum/#!topic/sci.chem/mwTOUCmGgiM>.
5. This experiment uses growing gummy bears but not to burn them. This activity soaks them in water, but in a slightly atypical, social, context. In this 5-class-period lab, “Gummy Bear Lab Meeting: Social Practices in a Scientific Community”, students “… participate in a scenario-based lab activity designed to help them define qualities that result in reliable and meaningful scientific research.” The source is the curriculum, *Social Nature of Scientific Research* from the Northwest Association for Biomedical Research (NWABR). (<http://nwabr.org/sites/default/files/GummyBear_7_20_13.pdf>) Both student and teacher materials are provided. This lesson was featured in NSTA’s *The Science Teacher* in the summer 2013 issue. There are four other lessons included in the complete 118-page curriculum, which can be found here: <http://nwabr.org/sites/default/files/NWABR_Social_Nature_Scientific_Research.pdf>.
6. After a thorough classroom discussion of density, a follow-up question to assess understanding might involve asking students how they could make a marshmallow sink in water. (<http://www.stevespanglerscience.com/blog/science-experiments/density-in-action-can-you-sink-a-marshmallow/>)
7. This series deals with paper chromatography to separate the colors used in making M&Ms®, Reese’s Pieces® and Skittles®.
8. This student experiment from About.com involves using paper chromatography to identify similarities and differences in coloring of various candies: <http://chemistry.about.com/od/chemistryexperiments/ht/candychroma.htm>.
9. Colors of candies make them attractive to eat. This one-page student lab activity uses paper chromatography to separate food colors in candy: M&Ms® or Skittles®: How Many Ways Can You See Red? *ChemMatters* **1999,** *17* (4), p 8).
10. Here is another student activity (with teacher information) from the *ChemSource®* program: <http://dwb.unl.edu/ChemSource/SourceBook/115FOOD.pdf>, *ChemSource®* “Food and Chemistry” Module, “Activity 2: Chromatographic Comparison of M&M™ Candies with Reese’s Pieces™”, pp 10–14.
11. And the December 1994 *ChemMatters* Classroom Guide includes a one-page student activity to separate colors of M&M® candies. (available on 30-year *ChemMatters* DVD, from ACS; see References section below for availability)
12. To show effects of air pressure on marshmallows—or rather the effects without air pressure—you might want to use this short (1:14) video from Steve Spangler Science’s “Sick Science” series that shows marshmallow “Peeps” expanding inside a container under vacuum: <http://www.stevespanglerscience.com/lab/experiments/growing-marshmallows>. Or else do it yourself! (if you have a vacuum pump—even a small hand pump can work reasonably well)
13. “A somewhat ‘wacky’ experiment that demonstrates production of light by the quick crushing of a spearmint-containing hard candy can be done as a demonstration. Something like a Lifesaver® can made to produce light by a quick hammer blow or by crushing the candy with a pliers, all done in a dark room. You might also be successful by having a student break the candy with their teeth. The reaction is referred to as *triboluminescence*. The following reference is a guide: “Chewing Light”, at <http://www.madsci.org/experiments/archive/860029125.Ch.html>. An explanation of the changes in electron positions within the atom is given at the following reference: the *Journal of Chemical Education*. American Chemical Society. **1979**, *56* (6), pp 413–414.

This activity is also found in Light Your Candy. *ChemMatters* **1990**, *8* (3), p 10.” (source: *ChemMatters* Teacher’s Guide. December 2008, p 61.)

1. To show students a good analogy to how we “count” atoms by weighing them, you can use M&M® candies, or other candies which come packaged with identical pieces. Just as we "count" out a mole of water molecules by weighing a sample of 18.00 grams, we can count M&Ms® in a similar manner. Suppose you required 1000 M&Ms® for an experiment. While a bag of M&Ms® states the total weight of a bag of candy, it does not tell you the number of candies it contains. Challenge the students with devising a method for determining the number of bags to purchase.

The answer would be to first weigh an M&M®, or better yet, weigh ten or so and find the "average" weight, in case there is a significant variation in individual weights. Then simply multiply this weight by 1000 to find the weight of 1000 M&Ms®. Divide by the weight of a bagful, and you know how many bags to purchase. (source: *ChemMatters* Teacher’s Guide. December 1999**)**

And these last activities just involve sugar, not candy specifically:

1. In movies, “sugar glass” is often substituted for real glass in a window for scenes when someone must go through the window. Sugar glass looks just like real glass, and it shatters just real glass, but the pieces don’t cut someone, as would real glass. Here’s a 2-minute video showing how to make sugar glass: <http://www.youtube.com/watch?v=3DHTJmDuw3A>.
2. Students can measure the boiling point elevation of maple syrup and compare it to a standard value in this lab activity from the University of Massachusetts: <http://lecturedemos.chem.umass.edu/PDFs/13.2_BoilingPointElevation.pdf>. Follow-up questions are also provided. Here is a newer version of the same experiment: <http://lecturedemos.chem.umass.edu/solutions13_2.html>.
3. This lab activity uses the 5E model of instruction to have students experiment with variables that could affect the rate of dissolving of sugar: <http://atlantis.coe.uh.edu/texasipc/units/solution/sugar.pdf>.

## Out-of-class Activities and Projects (student research, class projects)

Students can make their own simple candies at home (with parent approval/supervision).

1. Here are a few recipes for fudge, heating over the stove (the more traditional way):
2. <http://suzy-t.hubpages.com/hub/simple-homemade-fudge-recipe> (first recipe, using whole milk and corn syrup) and this one from the Exploratorium: <http://www.exploratorium.edu/cooking/candy/recipe-fudge.html>. (This one explains why several of the ingredients are needed.)
3. This one from Instructables comes complete with photos at various stages of fudge-making: <http://www.instructables.com/id/A-Christmas-Tradition-Old-Fashioned-Fudge/>. It also gives a choice of using cream of tartar or corn syrup; students may be interested in finding out why either would work—and what it (either one) does in the fudge-making process.
4. Here are two recipes for microwave fudge:
5. <http://recipes.howstuffworks.com/easy-microwave-fudge-recipe.htm>. Have students compare the chemistry of this recipe with a “normal” recipe that boils the water and sugar mixture, like those above. Notice that the microwave recipe uses powdered sugar. How might this affect the product? How can you find out?
6. Compare the above microwave recipe to this one: “Quick ‘No Cook’ Chocolate Fudge Recipe - A great kid-friendly recipe. No stove or whipping required” at <http://suzy-t.hubpages.com/hub/simple-homemade-fudge-recipe> (scroll way down to the last recipe that uses sweetened condensed milk and the microwave). What ingredients in the two recipes are the same? Different? What substance in one recipe substitutes for something else in the other recipe? Which fudge did you like better (assuming you made them both)?
7. Here are rock candy recipes:
8. From About.com, here is a simple recipe: <http://candy.about.com/od/hardcandyrecipes/r/rock_candy.htm>.
9. This one is more like a student experiment, but the product is the same: <http://www.sciencebob.com/experiments/rockcandy.php>.
10. And this one from the Exploratorium explains why some of the procedure needs to be done, and links to the chemistry of sugar: [https://www.exploratorium.edu/cooking/candy/recipe-rockcandy.html#](https://www.exploratorium.edu/cooking/candy/recipe-rockcandy.html).
11. To get students to focus on lab safety, have students observe one of the myriad online videos (that you choose) that show the thermal destruction of gummy bears, and have them analyze the video for unsafe lab procedures. (e.g., <http://www.youtube.com/watch?v=pTYl5adcv58> or this one, <http://www.youtube.com/watch?v=5vsy50IZSiY>).
12. The standard ”density” of maple syrup (66.5–66.7 oBx or % by mass) provides a boiling point 7–7.1 oF higher than the boiling temperature of water. It would be interesting to have students calculate the molal boiling point elevation of a solution of maple syrup (essentially sucrose) that is 66.5% or so content by mass and compare the result of that calculation to the temperature provided above. They could then hypothesize why their value is different than the standard value. Here is a series of calculations for reference: <http://lecturedemos.chem.umass.edu/PDFs/13.2_BoilingPointElevation.pdf>.
13. Students can grow their own crystals at home from chemicals other than sugar. This is an excellent site for ideas and advice about how to grow many different kinds of crystals: <http://www.waynesthisandthat.com/crystals.htm>.
14. Students could determine whether crystals are growing or shrinking by viewing their growth plumes. This NASA Quest site shows them how: <http://quest.arc.nasa.gov/space/teachers/mg/14crystal-growth.html>.

## References (non-Web-based information sources)



**30 Years of *ChemMatters***

Available Now!

**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013 and all available Teacher’s Guides, beginning February 1990). 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)**. Scroll about half way down the page and click on the *ChemMatters* DVD image at the right of the screen to order or to get more information.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online on the same Web site, above. Simply access the link and click on the “Past Issues” button directly below the “M” in the *ChemMatters* logo at the top of the Web page.**

Sweeting, L. Light Your Candy. *ChemMatters* **1990**, *8* (3), pp 10–12. The article discusses the phenomenon of triboluminescence, using Wint-o-green Lifesavers®, sugar cubes and adhesive tape, including emission spectra of light emitted by the crushed candy.

*ChemMatters* Teacher’s Guide. October **1990**, p 3. This part of the guide provides a more in-depth explanation of the luminescence involved in crushing the wintergreen candy.

Catelli, E. Peanut Brittle. *ChemMatters* **1991**, *9* (4), pp 4–7. The author describes the chemistry of crystalline vs. amorphous candies containing sucrose, and making peanut brittle, including the formation of hydroxymethylfurfural, which is involved in caramelization. The article includes a one-page student activity to make peanut brittle.

Alper, J. Crazy Candies. *ChemMatters* **1993**, *11* (3), pp 11–13. Author Alper discusses four different (way different) candies: Mad Dawg® bubble gum (not made any more), cotton candy, Face Slammers® Sour Gum (also discontinued), and Pop Rocks® (discontinued for a while, but now available again). He explains what make/made them so weird.

Baxter, R. Glass: An Amorphous Solid. *ChemMatters* ***1998****, 16* (3), pp 10–11. Author Baxter explains why glass (like cotton candy and other hard sugar candies) is considered an amorphous solid, and what it means to be an amorphous solid.

Rohrig, B. A Light of a Different Color. *ChemMatters* **1999**, *17* (2), pp 4–6. This article focuses on ultraviolet light, explaining the phenomena: phosphorescence, fluorescence and triboluminescence (the latter using Wint-o-Green Lifesavers as the example.

Vanderborght, C. Maple Syrup: Sweet Sap Boils Down to This. *ChemMatters* **2002**, *20* (2), pp 8–9. The article discusses the production and processing of maple syrup. Since maple syrup is a natural sugar, there are many overlaps in this article with the discussion in the present article. It includes information about making maple syrup fudge.

Tinnesand, M. What Makes Magic Tricks Tick? *ChemMatters* **2010**, *28* (3), “An Illuminating Trick”, p 7. Author Tinnesand treats triboluminescence as a magic trick, but he explains the chemistry behind the phenomenon.

Tinnesand, M. Sugar: An Unusual Explosive. *ChemMatters* **2010**, *28* (4), pp 5–7. Although sugar is not easily ignited, it can burn explosively if it is in dust form, where the immense surface area of the solid provides easy access for oxygen to mix and react with it (with an ignition source, such as a spark from metal rubbing on metal). This has happened many times in the past on a large scale in sugar refineries, where the sugar is processed into granular or powder consistencies. This article chronicles one such incident.

Rohrig, B. Myths: Chemistry Tells the Truth. *ChemMatters* **2010**, *28* (4), pp 8–10. In this article, author Rohrig discusses two myths that can be debunked by chemistry; one of them is that glass flows (over long periods of time). In order to explain why this one is not true, he goes into a fair amount of detail about the structure of glass, including discussion of the amorphous nature of glass (like amorphous candies).

The December 2010 *ChemMatters* Teacher’s Guide to the Rohrig article about myths above also contains more detailed information about the amorphous nature of glass and why peanut brittle is considered a glass.

Karabin, S. Did You Know? Structure of Matter: How Cotton Candy Is Made. *ChemMatters* **2011**, *29* (4), p 4. This short article does just what it says: it explains how cotton candy is made, with a touch of history to boot.

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Kawash, S. *Candy: A Century of Panic and Pleasure*; Faber and Faber, Inc.: New York, NY, 2013. This book provides a look back at the development of candy in the United States as a multi-billion dollar enterprise (more than $100 billion worldwide). Beginning with homemade candy in the 1850s, Dr. Kawash tells the reader how the industrial revolution and the development of media in advertising assured the worldwide rise of candy as a “food”.

Holden, A. and Singer, P. Crystals and Crystal Growing; MIT Press; Cambridge, MA, 1982. The book by Holden and Singer is a classic. Originally published in 1960, it has stood the test of time. It was originally written as a supplementary book for high school students and describes the basic principles of crystals and crystal-growing, and it provides experiments for students to do to grow their own crystals.

## Web Sites for Additional Information (Web-based information sources)

**More sites on** **the history of candy**

This site is called a food timeline, but it doesn’t resemble a normal timeline. It does, however, provide a wealth of information about the history of candy, including descriptions of a long list of various types of candies (and it IS roughly in chronological order). (<http://www.foodtimeline.org/foodcandy.html>)

There are many other candy timelines on the Web, but most of them are brief histories, beginning around 1850, of U.S. candy making, not worldwide candy history (e.g., <http://www.candyhistory.net/candy-origin/candy-timeline/>). Most are made and maintained by online candy stores, especially those that sell “retro” candies.

**More sites on** **types of sugar**

A list of all the various types of sugar, along with a description of each can be found here: <http://whatscookingamerica.net/Sugar.htm>.

Here’s another one: <http://candy.about.com/od/candybasics/a/sugarguide.htm>.

This site provides a brief description of how maple syrup is made from tree sap; it includes photos of the boiling/evaporation process that concentrates the sap: <http://www.mnmaplesyrup.com/LearnBoiling.aspx>.

**More sites on** **sugar-based candies**

Here’s a Web page from about.com that provides a chart of temperatures and sugar stages: <http://candy.about.com/od/candybasics/a/candytemp.htm>.

This site describes and shows pictures of each of the stages of heating the sugar solution—thread, soft ball, firm ball, hard ball, soft crack, hard crack, and caramel: <http://candy.about.com/od/candybasics/ss/candytempsbs.htm>.

This Exploratorium page describes the various stages of heating the sugar solution to make candy: <http://www.exploratorium.edu/cooking/candy/sugar-stages.html>. There are video clips for each stage also, but this editor was unable to open any of them. Both QuickTime® and RealPlayer® versions are there, but the QuickTime® versions are not available and the RealPlayer® versions didn’t open.

“What’s That Stuff?” is a feature in *Chemical and Engineering News*, published by the American Chemical Society. These articles provide (usually) a one-page description of a specific everyday item. This article, titled simply “Marshmallow”, provides an explanation of marshmallows, with a bit of history and quite a bit of chemistry. (<http://cen.acs.org/articles/84/i16/Marshmallow.html>) (Petkewich, R. What’s That Stuff? Marshmallow. *Chem. Eng. News* **2006**, *84* (16), p 41)

This Exploratorium site provides a series of activities about candy for students. Included are: the science of sugar; an animated, interactive, multi-level “Candy-o-Matic” site that shows what happens as temperature is increased in a sugar solution; a “Kitchen Lab” series of candy recipes; and a simulated thermometer that relates temperature to the stages of sugar’s heating, clicking on each temperature setting provides a recipe for a candy of the type that forms at that stage: <http://www.exploratorium.edu/cooking/candy/>.

**More sites on** **candy recipes**

Here are several recipes for making rock candy:

* From the San Francisco Exploratorium Web site: [https://www.exploratorium.edu/cooking/candy/recipe-rockcandy.html#](https://www.exploratorium.edu/cooking/candy/recipe-rockcandy.html). This site also has a link to another page telling students what sugar is, complete with a ball-and-stick model of sucrose, and describing the process of dissolving of the sugar with heat and recrystallization upon cooling. It also includes discussion of ways to prevent crystallization from occurring (in other candies such as fudge).
* This is a video recipe and instructions from About.com: <http://video.about.com/chemistry/How-to-Make-Rock-Candy.htm>. Note that the video instructions differ from those given in the 10-screen online “print” version (<http://candy.about.com/od/phototutorials/ss/sbs_rock_candy.htm>), in that the video says to put the sugar and water in the pan from the beginning and heat together, whereas the online instructions say to heat the water to boiling first and then add the sugar.
* This About.com page discusses a few problems with growing rock candy crystals: <http://chemistry.about.com/od/growingcrystals/a/sugarcrystals.htm?utm_term=simple%20rock%20candy%20recipes&utm_content=p1-main-6-title&utm_medium=sem&utm_source=msn&utm_campaign=adid-6b03ebcc-64e8-4c44-b803-1ca0fb2c454f-0-ab_msb_ocode-5995>, and this About.com video provides a few tips to ensure crystal formation: <http://video.about.com/chemistry/3-Tips-for-Growing-Sugar-Crystals.htm>
* Here’s a recipe that for rock candy you may (or may not) want to share with kids. It’s a recipe for making the blue crystal meth from TV’s “Breaking Bad” (turns out it was just rock candy after all): <http://chemistry.about.com/od/sugarcrystalsrockcandy/a/Breaking-Bad-Blue-Crystal-Meth-Rock-Candy-Recipe.htm>

And here are a few recipes for making fudge:

* This is a recipe from Kraft using their Jet-Puffed Marshmallow Crème: <http://www.kraftrecipes.com/recipes/fantasy-fudge-51833.aspx>. This recipe includes nutritional information.
* Here is the original version, almost the same as the one above. (This is the one this editor used for years, making the special treat as a gift for family and friends.) <http://www.christmas-cookies.com/recipes/recipe191.fantasy-fudge.html>
* Here’s a video (4:33) showing a cotton candy maker who enjoys his job, and makes everyone around him enjoy it too! (<https://www.youtube.com/watch?v=AmfvY0vusyE>)

**More sites on** **crystal formation and growing crystals**

This page discusses eight different methods for growing x-ray-quality crystals: <http://chem.chem.rochester.edu/~nvd/crystalgrowth.html>.

This site provides concise directions for many different student experiments for growing crystals of various materials. The author of the site has tried almost all of the experiments himself, so they are well-tested. He has also tested various extensions to many of the procedures and offers lots of advice. Two experiments in particular are of interest to readers of this Teacher’s Guide: “Rock Candy” (under the *Advanced crystal growing projects* tab), and “Sugar Crystals” (Under the *Growing large, high quality single crystals* tab). (<http://www.waynesthisandthat.com/crystals.htm>)

This is the NASA Quest site referenced in the background information section about observing growth plumes in crystal growth: <http://quest.arc.nasa.gov/space/teachers/mg/14crystal-growth.html>.

**More sites on the effect of changing variables (e.g., stirring, rate of cooling) on crystal size**

Earth science teachers use this type of precipitation activity to demonstrate how the rate of cooling affects crystal size in rocks. (<http://www.rsc.org/Education/Teachers/Resources/jesei/cooling/index.htm>) Granite, a metamorphic rock, typically has large grains, indicating large crystals, while rock like rhyolite, an igneous rock, has very small crystals, due to granite’s cooling very slowly, deep underground, insulated by other rock around it to slow its cooling, while rhyolite oozes out of volcanoes and cools quickly on the land’s surface or, if it flows into the ocean, it cools and hardens immediately upon contact with water, both of which processes preclude the time needed to form large crystals. Note that this activity uses lead iodide, which may not be allowed to be used in your classroom lab.

Here’s another lab that uses alum (a pickling spice) or copper sulfate (sold as a root killer in hardware stores) to accomplish the same task: <http://pirate.shu.edu/~schoenma/rockCycleWeb/pdfFiles/CrystalSizaCoolingRate.pdf>. And here is one more lab that uses magnesium sulfate (Epsom salts): <http://www.sas.upenn.edu/~jbryson/IgneousLab.pdf>.

**More sites on carbohydrates—mono- and di-saccharides**

This site provides discussion about and structural formulas for many carbohydrates, mono-, di- and polysaccharides: <http://chemistry2.csudh.edu/rpendarvis/monosacch.html>.

**More sites on** **sucrose decomposing upon heating**

This article from Science Daily appeared on August 2, 2011: <http://www.sciencedaily.com/releases/2011/07/110725123549.htm>.

And this one from Gizmodo is similar: <http://gizmodo.com/5824822/scientists-in-sugar-shock-after-finding-sucrose-doesnt-melt>.

**More sites on** **how candies “work”**

The phenomenon of triboluminescence (light emission from crunching hard candies) is explained here: <http://chemistry.about.com/cs/howthingswork/a/aa060601a.htm>.

These two Web sites discuss how Pop Rocks® Candy works: <http://chemistry.about.com/od/howthingsworkfaqs/f/poprockscandy.htm> and

<http://science.howstuffworks.com/innovation/science-questions/question114.htm>.

**More online videos on various topics about candy**

This video shows how to make sugar glass, substitute for real glass in movies that involve breaking of the “glass”. (2:03 video, after short ad: <http://on.aol.com/video/sugar-glass-recipe-517192434>)

This video shows how sugar is extracted from sugar cane. (9:35 video: <http://www.youtube.com/watch?v=ZBOou6cahtw>)

This video shows a commercial manufacturer making ribbon candy (1:34 video—Christmas Carol background music, no discussion, following a short ad: <http://www.youtube.com/watch?v=C9jAd6NRMW0&feature=player_embedded>)

Ever wonder how jelly beans are made? Check it out here. (4:40 video: <http://www.youtube.com/watch?v=J2g2RVed4nI>)

Or candy canes? (4:54 video: <http://www.youtube.com/watch?v=1OMx7xhxu70>)

Or smiley face hard candy? (26:00 video: <http://www.youtube.com/watch?v=FcAEw8UA7II>)

Dr. Richard Hartell from the University of Wisconsin-Madison shows how to make cotton candy, from Bytesize Science, an American Chemical Society production. (1:54 video clip: <http://www.youtube.com/watch?v=qm6RcneM7kA>)

This is the 1-1/2 hour-long “Bitter Truth on Sugar” lecture video by Dr. Robert Lustig, Doctor of Pediatrics at the University of California, San Francisco. He maintains that fructose in sugar and high fructose corn syrup (both about 50% fructose) are the cause of today’s obesity epidemic—“They are dangerous … Sugar is a poison.” (1:30:00 video: <http://www.youtube.com/watch?v=dBnniua6-oM>)

## General Web References (Web information not solely related to article topic)

PhET, from the University of Colorado, Boulder, provides a wealth of teacher-prepared materials, all built around an extensive series of computer simulations that can be downloaded, or accessed directly from their site. Their collection of simulations includes all sciences and all levels of students. The ancillary materials include labs, worksheets, question sets and demonstrations. Choose a science topic from their pull-down list and browse the available materials on that topic. You might also want to inform your science colleagues of the site’s existence. (<http://phet.colorado.edu/>)

These Web sites contain the complete first version of the NSF-sponsored program *ChemSource®*: <http://chemmovies.unl.edu/chem_source_pdf/ChemSource.html> (Don’t let the “chemmovies” in the title fool you.), or <http://dwb.unl.edu/ChemSource/ChemSource.html>.

The Web site contains materials in pdf format that are the equivalent of 4- very thick binders of information for all chemistry teachers. Each of the 40 modules (48 modules in the second edition) that comprise the major topics of (and go beyond) the typical high school chemistry course includes invaluable materials for both teacher and student. These include performance objectives, central concepts, labs, demonstrations, group activities and discussion topics, links to other chemistry topics and to everyday life, student misconceptions, humor, history, A-V aids, references, and appendices containing ancillary materials for the teacher.

Version 3.0 of the *ChemSource®* materials is available on DVD from ACS ($60): <https://www.store.acs.org/eweb/ACSTemplatePage.aspx?site=ACS_Store&WebCode=storeItemDetail&parentKey=cbf9d4e6-3ae0-411c-95d3-12808813daf1>.

# Performance-Enhancing Drugs: Is Winning Everything?

## Background Information (teacher information)

How widespread is the use of performance-enhancing drugs among adolescents? According to the Center for Disease Control and Prevention “Youth Risk Behavior Report” for 2011:

Nationwide, 3.6% of students had taken steroid pills or shots without a doctor's prescription one or more times during their life (i.e., ever took steroids without a doctor's prescription) ([Table 57](http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6104a1.htm#Tab57)). Overall, the prevalence of having ever taken steroids without a doctor's prescription was higher among male (4.2%) than female (2.9%) students; higher among black male (4.5%) than black female (1.3%) students; and higher among 10th-grade male (4.0%) and 12th-grade male (3.7%) than 10th-grade female (2.3%) and 12th-grade female (1.9%) students, respectively. Overall, the prevalence of having ever taken steroids without a doctor's prescription was higher among Hispanic (4.3%) than black (2.9%) students and higher among white female (2.8%) and Hispanic female (4.3%) than black female (1.3%) students. Overall, the prevalence of having ever taken steroids without a doctor's prescription was higher among 9th-grade (4.2%) than 12th-grade (2.8%) students and higher among 9th-grade female (3.9%) than 12th-grade female (1.9%) students. The prevalence of having ever taken steroids without a doctor's prescription ranged from 1.8% to 6.1% across state surveys (median: 3.4%) and from 1.8% to 5.2% across large urban school district surveys (median: 3.7%) ([Table 58](http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6104a1.htm#Tab58)).

Among students nationwide, the prevalence of having ever taken steroids without a doctor's prescription increased during 1991–2003 (2.7%–6.1%) and then decreased during 2003–2011 (6.1%–3.6%). The prevalence of having ever taken steroids without a doctor's prescription did not change significantly from 2009 (3.3%) to 2011 (3.6%).

(<http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6104a1.htm>)

An article published in the journal *Pediatrics* in 2012, indicated that:

**OBJECTIVE:** Media images of men and women have become increasingly muscular, and muscle-enhancing techniques are available to youth. Identifying populations at risk for unhealthy muscle-enhancing behaviors is of considerable public health importance. The current study uses a large and diverse population-based sample of adolescents to examine the prevalence of muscle-enhancing behaviors and differences across demographic characteristics, weight status, and sports team involvement.

**METHODS:** Survey data from 2793 diverse adolescents (mean age = 14.4) were collected at 20 urban middle and high schools. Use of 5 muscle-enhancing behaviors was assessed (changing eating, exercising, protein powders, steroids and other muscle-enhancing substances), and a summary score reflecting use of 3 or more behaviors was created. Logistic regression was used to test for differences in each behavior across age group, race/ethnicity, socioeconomic status, BMI category, and sports team participation.

**RESULTS:** Muscle-enhancing behaviors were common in this sample for both boys and girls. For example, 34.7% used protein powders or shakes and 5.9% reported steroid use. Most behaviors were significantly more common among boys. In models mutually adjusted for all covariates, grade level, Asian race, BMI category, and sports team participation were significantly associated with the use of muscle-enhancing behaviors. For example, overweight (odds ratio = 1.45) and obese (odds ratio = 1.90) girls had significantly greater odds of using protein powders or shakes than girls of average BMI.

**CONCLUSIONS:** The use of muscle-enhancing behaviors is substantially higher than has been previously reported and is cause for concern. Pediatricians and other health care providers should ask their adolescent patients about muscle-enhancing behaviors.

(<http://pediatrics.aappublications.org/content/early/2012/11/14/peds.2012-0095.abstract>)

A more recent report in 2014, from MarketWatch online reported even more concerning numbers about steroids and human growth hormone:

NEW YORK, July 23, 2014 New, nationally projectable survey results released today by the [Partnership for Drug-Free Kids](http://www.drugfree.org/) confirmed a significant increase – a doubling – in the reported lifetime use of synthetic human growth hormone (hGH) among teens. According to the latest Partnership Attitude Tracking Study (PATS), sponsored by [MetLife Foundation](http://www.metlife.org/),11 percent of teens in grades 9-12 reported "ever having used" synthetic human growth hormone without a prescription, up dramatically from just 5 percent in 2012.

These findings underscore teens' growing interest in performance enhancing substances, as well as the need for tighter regulation and more accurate labeling of "fitness-enhancing" over-the-counter products implying they contain synthetic hGH . . .

. . . African-American and Hispanic teens are more likely to report use of synthetic hGH, with 15 percent of African-American teens, 13 percent of Hispanic teens and 9 percent of Caucasian teens saying they used synthetic hGH at least once within their lifetime. Both boys and girls report use of synthetic human growth hormone and steroids without a prescription. The PATS study found no significant difference between the proportions of teen boys vs. teen girls, who report using synthetic hGH (12 percent vs. 9 percent, respectively).

In addition to the reported increase in teen use of synthetic hGH, PATS confirms a gradual, long-term increase in teens' reported lifetime use of steroids. Steroid use among teens has increased from 5 percent in 2009 to 7 percent in 2013. The PATS data show a strong correlation between the use of synthetic hGH and steroids. Currently, one in five teens (21 percent) reports that at least one friend uses steroids, and another one in five teens (21 percent) believes it is easy to obtain steroids. Both of these measures improved in 2010 and have since remained consistent.

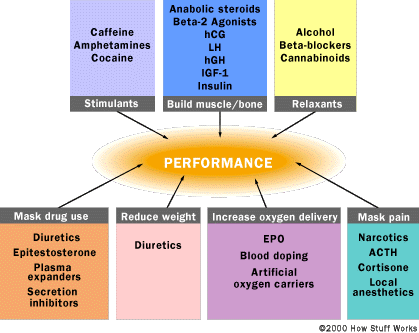
(<http://www.marketwatch.com/story/national-study-teens-report-higher-use-of-performance-enhancing-substances-2014-07-23>)

The topic is an important one for students to understand, and can provide you with an opportunity to discuss with your students the importance of their being aware of the scientific evidence about performance-enhancing drugs.

Although the article emphasizes anabolic steroids and blood doping, these are only two of a broader array of performing enhancing drugs. The World Anti-Doping Agency (WADA), the international agency that monitors drugs prohibited in sports, lists five classes of prohibited substances: anabolic agents, peptide hormones and growth factors, beta-2 agonists, hormone and metabolic modulators and diuretics. It will not be possible in this Teacher’s Guide to list them all, but you can check many of the web links to see more comprehensive lists. We will emphasize steroids and blood doping and provide additional information on the PEDs listed in the WADA manual.

WADA was established in 1999 as an international independent agency composed of and funded equally by the sport movement and governments of the world. Its key activities include scientific research, education, development of anti-doping capacities, and monitoring of the World Anti Doping Code (Code)—the document harmonizing anti-doping policies in all sports and all countries. WADA is a Swiss private law Foundation. Its seat is in Lausanne, Switzerland, and its headquarters are in Montreal, Canada.

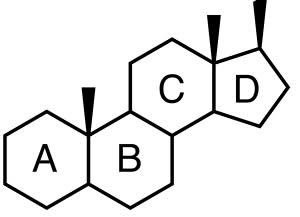
Below is a summary of the most common PEDs from How Stuff Works:



(<http://entertainment.howstuffworks.com/athletic-drug-test1.htm>)

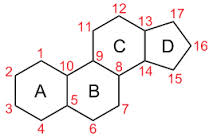
**More on** **anabolic steroids**

Anabolic agents, primarily hormones, are substances that promote tissue growth, as opposed to catabolic agents, which promote tissue breakdown. Anabolic agents are, as the article describes, primarily steroids. This chemical description of steroids was adapted from the *ChemMatters* Teacher’s Guide for “Those Raging Hormones”, December 2010:

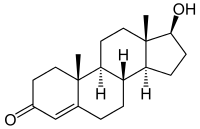
Chemically, steroids all have a basic four-ring structure in common. There are three six-sided (cyclohexane) rings along with one five-sided (cyclopentane) ring. See the diagram below right. Rings A-C are the cyclohexane rings and ring D is the cyclopentane ring.

This four-ring structure forms the backbone of the cholesterol molecule. Functional groups may be added to the basic structure to produce analogs. Cholesterol is classified as a lipid compound. Most lipids are fat-soluble, allowing them to pass through cell walls easily. Steroids help control metabolism, inflammation, electrolyte balance in the body, and, most importantly, in the context of the article, they help to build muscle mass.

Even though the article includes a diagram of the steroid nucleus with the carbon atoms numbered, we are providing the diagram below for your reference. For additional details on steroid nomenclature and numbering, see <http://www.chem.qmul.ac.uk/iupac/steroid/>.

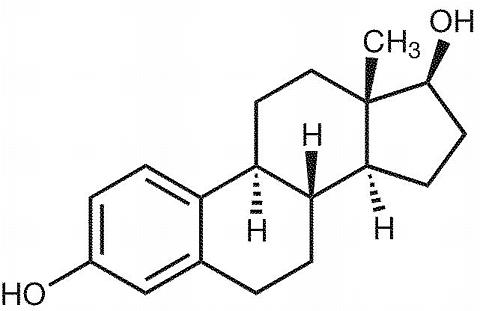
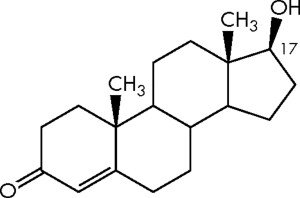
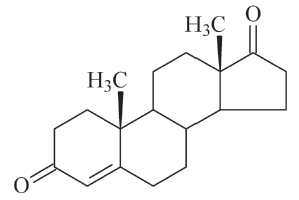


(<http://commons.wikimedia.org/wiki/File:Steran_num_ABCD.svg>)

 The body produces steroids naturally. In males, cortisol and testosterone are the main steroids, and these are functionally considered hormones. The main steroid hormones in females are estrogen and progesterone. Among other functions, these steroids build muscle and bone mass by stimulating tissue to produce more protein. It is very important to note to students that, as the article says, what we commonly refer to as “anabolic steroids” are actually synthetic versions of testosterone and its derivatives. They are created chemically in laboratories to mimic and augment the natural version. The chemical structure of testosterone is shown at left. Derivative compounds add varying functional groups to the basic testosterone structure. In addition to testosterone, commonly used steroids include dihydrotestosterone, androstenedione (andro), dehydroepiandrosterone (DHEA), clostebol and nandrolone. These synthetic steroids stimulate skeletal muscle growth by triggering more rapid protein development. This is the basic reason why athletes use PEDs—the added muscle enhances athletic performance.

However, they also have potentially harmful side-effects. Because steroids are broken down in the liver, they may cause jaundice and other liver damage. Other well-documented side-effects include mood swings, depression and aggression, because steroids act on various centers of the brain. In **males they** may interfere with normal sexual function and cause baldness, infertility and breast development. In **females** they cause male characteristics to develop and interfere with normal female functions.

Another steroid related to testosterone is androstenedione, which is a naturally-occurring human hormone. It is a precursor of both testosterone and estradiol, which means it is converted into those substances in the body. It is a controlled substance, available legally by prescription only. You can compare the three structures below to see the similarities.



Androstenedione Testosterone Estradiol

(<http://www.huvepharma.com/products/view/176>)

(<https://knowledgeserver.wordpress.com/2011/08/04/testosterone/comment-page-12/>)(<http://www.theodora.com/drugs/estrogel_006_solvay.html>)

Testosterone is a sex hormone produced by the testes that encourages the development of male sexual characteristics and stimulates the activity of the male secondary sex characteristics. Chemically, testosterone is 17-beta-hydroxy-4-androstene-3-one.

Estradiol is a white crystalline powder, chemically described as estra-1,3,5(10)-triene-3,17 (beta)-diol. It has an empirical formula of C18H24O2 and molecular weight of 272.39. It is the principal estrogenic hormone. That is, it is the most important hormone that causes female sex characteristics.

Note that androstenedione—commonly called “andro”—can be converted to testosterone by a very small change at 17 oC, and can be converted to estradiol by another small change at 3 oC. It is, therefore, another PED used by athletes in an attempt to gain an advantage. Athletes who abuse andro hope that the extra amount of the drug in their body will be converted to testosterone to build muscle and prolong workouts. There is some research, however, that debunks the effectiveness of andro, indicating that most of the synthetic version of the drug is actually converted to estradiol.

The side effects in men include shrinking of the testicles, diminished sperm production, acne and breast enlargement. Females risk masculinization and acne. In both sexes andro decreases HDL cholesterol which may lead to increased risk of stroke or heart attack.

**More on blood doping**

In order to understand how blood doping, the second of the performance-enhancing methods described in the article, works, your students may need a quick review of the way blood circulates oxygen to cells throughout the body.

The cells in our bodies require oxygen for cellular respiration. Oxygen enters the lungs when we inhale. In the lungs oxygen diffuses across the very thin walls (less than 1 micrometer thick) of the more than 300 million alveoli and passes into the bloodstream via capillaries in the circulatory system. Alveoli provide a surface area of more than 70 m2 to permit the gas exchange to occur. Even so, only about 50% of the inhaled O2 migrates to the blood from the lungs.

The oxygen transport process is dependent on the partial pressure of oxygen in the system. Henry’s Law describes this relationship:

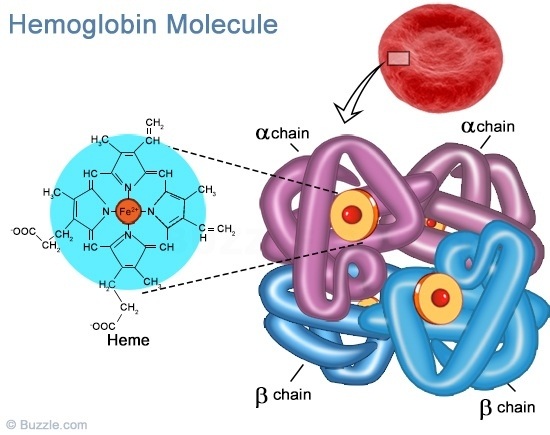
p = (Kh)(c)

where *p* is the partial pressure of the gas above the solution, *c* is the concentration of the dissolved gas and *Kh*is a constant (Henry’s constant) with the dimensions of pressure divided by concentration. Inhaled oxygen in the lungs has a relatively high partial pressure compared to the partial pressure of O2 in the blood stream. So oxygen will dissolve in the blood directly but only slightly due to the low solubility of oxygen in water.

The partial pressure of oxygen also influences positively the ability of hemoglobin to take up oxygen. The relatively higher oxygen partial pressure at the lung-blood stream interface causes oxygen to be bonded to hemoglobin molecules once the blood is saturated with dissolved molecular oxygen. As the blood moves through the arterial circulatory system to peripheral cells, it encounters cells with lower oxygen partial pressures because aerobic respiration is taking place here, using up oxygen. In these peripheral cells (muscle cells, for example) oxygen is being used up and carbon dioxide is being produced. So in these cells the partial pressure of CO2 is higher and it is dissolved in the venous blood to be returned to the lungs as the article notes.

As noted above, a small amount (about 2%) of oxygen dissolves in molecular form in the blood, but most is bonded to hemoglobin (Hb) molecules, which are densely packed proteins in human red blood cells. Hemoglobin is important because oxygen is not very soluble in water (major blood component) and so it is the Hb that transports most oxygen to the cells. There are approximately 150,500,000,000,000,000,000 hemoglobin molecules in 100 ml of whole blood. Each of these Hb molecules can transport four molecules of oxygen.

How does Hb transport oxygen? Hemoglobin’s structure is shown below. It is a globular protein. That is, it is folded in such a way as to form an approximate sphere. Folding of protein molecules is the result of hydrogen bonding between atoms within the large, complex molecule. There are four protein sub-units that make up the molecule (blue and purple in the diagram)—two α-globin chains and two β-globin chains. The chains are folded and inside each of the folds is a planar structure called a porphyrin (left side of diagram). At the center of the porphyrin is an Fe+2 ion. The iron-porphyrin structures are called hemes. In chemical terms the porphyrin structure is called a ligand which forms a bond with the iron. Recall that ligands are neutral molecules or ions that have a lone electron pair that can be used to form a bond to a metal ion. The bonds that are formed using the electron pair from the ligand will therefore, by definition, be coordinate covalent bonds. Iron has a coordination number of 6, meaning that it can form six such bonds. In the heme structure, the iron is bonded to a) four nitrogen atoms that make up the porphyrin structures. The nitrogen atoms contribute the lone pair; b) one more nitrogen that connects to a histidine protein from the larger hemoglobin molecule; and c) finally, to a molecule of oxygen.



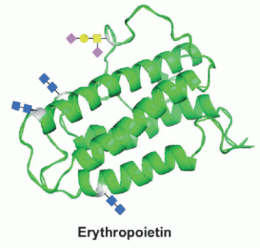
(<http://www.buzzle.com/articles/structure-of-hemoglobin.html>)

As oxygen enters the blood, each of the four heme structures in the hemoglobin molecule binds one oxygen molecule and then the Hb molecule transports the four molecules to other parts of the body. Each gram of Hb can combine with 1.34 ml of oxygen. Normal blood contains about15g Hb/100ml of blood so the oxygen carrying capacity of Hb is 20 ml oxygen/100 ml blood. As the blood circulates to periphery cells the dissolved molecular oxygen is used first by the cells. This reduces the partial pressure of oxygen in the blood and as a result the oxygen is more easily released from the hemoglobin molecule to enable aerobic cellular respiration.

You can see that the oxygen content of the blood and, therefore, the oxygen available in cells, especially muscle cells in this context, is dependent on the hemoglobin content of the blood. More hemoglobin would mean more available oxygen and that, in turn, would mean that athletes could exercise longer or more strenuously. That would lead to enhanced performance.

Athletes try to increase available oxygen in the blood by 7 to 10 per cent by taking erythropoietin or, more specifically, its synthetic form called epoetin. This protein is produced in the kidneys and it stimulates bone marrow to produce red blood cells (erythropoiesis). More blood cells means more hemoglobin and more hemoglobin means more oxygen available to cells during periods of extreme exertion.

EPO is actually not one compound but a large family of molecules. Known as glycoproteins, the structures are composed of a protein with four carbohydrate sectors as shown in blue, yellow and purple in the schematic below. The protein portion is always the same, as are the locations at which the carbohydrate domains are attached.

Since the development of a synthetic form of EPO in 1985, it is possible to artificially stimulate hemoglobin production by injecting the synthetic form into the body.

Erythropoiesis-stimulating agents (ESAs) like EPO are most often used as blood doping agents in endurance sports, such as cycling, rowing, distance running, cross country skiing, the biathlon, and the triathlon. It was EPO that was abused by many cyclists, including Lance Armstrong.

The health risks of using EPO include increased chances of heart attack, stroke and pulmonary edema. Some researchers theorize that the drug thickens the blood to the point where it produces fatal clots.

In addition to injecting EPO in order to increase the oxygen content of the blood, it is possible to inject artificial oxygen carriers that can transport oxygen in the blood stream. Chemicals that have been used for this purpose include perfluorocarbons and synthetic hemoglobins. Another method of enhancing the blood is to infuse whole blood into an athlete just before competition.

Still another method is to train at high altitudes where O2 concentration is lower than at sea level. At 8000 ft. elevation, for example, the oxygen concentration in the atmosphere is about 75% of that at sea level. As a result, the partial pressure of O2 in the blood is lower and that, in turn, stimulates increased red blood cell production. If athletes who train this way then return to sea level conditions their blood will have added oxygen carrying capacity and a competitive advantage.

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**More on other PEDs**

The remainder of this section will provide less detailed information on PEDs not discussed in the article.

**Human growth hormone** (hGH) acts in a way similar to that of anabolic steroids. It increases muscle mass. The substance occurs naturally in the human body; the pituitary gland produces it to stimulate growth in children and adolescents and to increase [muscle](http://health.howstuffworks.com/human-body/systems/musculoskeletal/muscle.htm) mass in adults. The synthetic form is used as a PED. It stimulates the production of male and female sex hormones, but is only effective in increasing muscle mass in males. It is also the hormone detected in most home pregnancy kits. Health risks include joint pain, muscle weakness, fluid retention, hypertension and diabetes.

**Beta-2 Antagonists** – The best known of this group is albuterol, which is used to prevent and treat wheezing, shortness of breath, coughing, and chest tightness caused by lung diseases such as asthma and chronic obstructive pulmonary disease (COPD). It is in a class of medications called bronchodilators that work by relaxing and opening air passages to the lungs to make breathing easier. Why would drugs like this be used to enhance athletic performance? Remember the intent of blood doping (see above)—it is to increase oxygen flow to muscle cells. Some athletes believe that using beta-2 antagonists actually increases lung capacity thereby increasing oxygen flow. Research indicates that inhaled albuterol does not improve athletic ability, but the drug can be taken orally (swallowed) or by injection. Administered this way, the drug behaves like an anabolic steroid—it increases muscle mass. Other drugs in this class include clenbuterol, terbutaline, slabutamol, fenoterol and bambuterol. Health risks include nausea, dizziness, headaches, muscle cramps and rapid heartbeat.

**Hormone and Metabolic Modulators –** These are chemicals that inhibit or moderate the effects of other substances in the body. For instance hormone modulators limit the production or effectiveness of the body’s hormones. One such recent anti-doping case involving the hormone modulator tamoxifen is described on the What Works web site:

In June 2012, outfielder Marlon Byrd faced a 50-game suspension after testing positive for **tamoxifen**, a substance banned from [Major League Baseball](http://entertainment.howstuffworks.com/american-vs-national-baseball-league.htm) and many other sports. Why would an athlete want to take a drug normally used by breast-cancer patients? The answer lies in some interesting biochemistry.

Many breast cancers have receptors for estrogen, a hormone that promotes the development and maintenance of female characteristics of the body. When estrogen molecules fit into these receptors, like a key fitting into a lock, the malignant cells become activated. Tamoxifen blocks these estrogen receptors, interfering with the cancer's ability to grow and develop. This is why scientists refer to tamoxifen as an anti-estrogenic agent.

Now let's turn our attention to a home-run slugger taking steroid injections -- usually synthetic testosterone -- to grow his [muscles](http://health.howstuffworks.com/human-body/systems/musculoskeletal/muscle.htm). Large doses of the male hormone cause the body to produce additional estrogen. This in turn can result in enlarged breasts, a feature that most power hitters find unappealing. To counteract the effects of estrogen and mask their steroid use, these players may opt to take tamoxifen. That means anti-estrogens don't really enhance performance, but, because they alleviate symptoms of PEDs, they appear on the World Anti-Doping Agency's list of more than 200 banned substances and methods.

(<http://science.howstuffworks.com/10-performance-enhancing-drugs.htm#page=9>)

An important banned metabolic modulator is insulin. Although we think of it in the context of diabetes, it is actually an anabolic agent. Insulin helps to move glucose and amino acids into muscle cells and aids in the synthesis of glycogen, lipids and proteins, thereby creating more lean muscle mass. Combined with anabolic steroids, it prevents muscle tissue breakdown. The synthetic form is used as a PED.

For a more extensive list of these modulators see <https://sites.google.com/site/playingclean/Is-It-Banned/banned-substances-at-all-times/hormone-and-metabolic-modulators>.

You can see the complete list of substances and other methods of enhancing sports performance prohibited by the World Anti-Doping Agency here: <http://www.usada.org/wp-content/uploads/2014-wada-prohibited-list.pdf>.

**Diuretics** are drugs that change the body’s natural balance of electrolytes, primarily sodium and chlorine. Their typical mode of action is to increase the concentration of sodium ion in urine, and as a result the volume of water that is turned into urine is also increased. So the total volume of urine is increased. The net effect is to dilute all the solutes in urine, including any PEDs or their metabolites. Athletes using PEDs hope that the reduction in PED concentration in urine will decrease the chances of PEDs being discovered in the urine. Diuretics are sometimes thought of as masking agents for PEDs. This loss of water can also decrease an athlete's weight, helping him or her to compete in a lighter weight class, which many athletes prefer.

## Connections to Chemistry Concepts (for correlation to course curriculum)

1. **Organic compounds**—All of the chemical compounds described in the article are organic.
2. **Synthetic compounds**—Most of the chemicals described in the article occur in nature but it is a synthetic analog of each that is abused as a PED.
3. **Biochemistry**—The article is a good starting point for a conversation with students about the interdisciplinary nature of modern chemistry—in this article, the way chemistry and biology are intertwined.
4. **Hormones**—Most of the PEDs are, in fact, human hormones, compounds that regulate body processes.
5. **Aerobic respiration**—All of the blood doping discussion in the article is based on the oxygen needs of aerobic cellular respiration.
6. **Chemistry and health**—Students should be aware of how much of their health is based on chemical processes functioning normally and how these processes can be altered by chemicals they consciously put into their bodies.
7. **Coordination chemistry**—The hemoglobin-oxygen connection, the process that underlies blood doping, is the result of coordination complexes.
8. **Henry’ s Law**—Oxygen solubility, in molecular form and as part of hemoglobin, is dependent on the partial pressure of oxygen in the system.
9. **Solubility**—The concentration of many substances referred to in the article is a major factor in PED use—oxygen in blood, PEDs in urine, and increased concentration of steroids in the body are examples.

## Possible Student Misconceptions (to aid teacher in addressing misconceptions)

**“All performance-enhancing drugs are illegal—in addition to being banned by sports governing agencies.”** *All of the PEDs discussed in the article and in this Teacher’s Guide are illegal to use without a prescription. See* [*http://www.deadiversion.usdoj.gov/pubs/brochures/steroids/professionals/*](http://www.deadiversion.usdoj.gov/pubs/brochures/steroids/professionals/) *for more on the law. However, there are hundreds of over-the-counter supplements and other products that are available in stores and on the internet. For example, here is a listing of a few of these available products: bicarbonate, beta-hydroxy-beta-methylbutyrate (HMB), creatine, calcium, carbohydrate powders and gels, glucosamine and chondroitin, intramuscular iron, intramuscular vitamin B12, liquid meal replacements, melatonin, recovery formulas, sports energy bars, skim milk powder, sports drinks, and specific vitamins and minerals.*

## Anticipating Student Questions (answers to questions students might ask in class)

1. **“Aren’t all steroids bad for you?”** *No, all steroids are not harmful to humans. You are probably thinking of artificial anabolic steroids that are taken by athletes to enhance performance. Many chemical compounds, some of them occurring naturally in the body and some that are used as medicines, are steroids. The term “steroid” refers to a specific chemical structure, not to something that is bad.*
2. **“The term ‘synthetic analog’ is used in the article. What is that?”** *Students probably understand that “synthetic” refers to a substance that is made from shelf chemicals rather than extracted from nature. As the term “analog” is used in the article, it refers to a molecule that has been synthesized to be either identical to the naturally-occurring molecule or to be a slight variation of the natural molecule that is more effective than the original. The sentence in the article that describes this is “*In laboratories, scientists change the chemical structure of testosterone to maximize its performance.”
3. **“Both steroids and blood doping agents are referred to as ‘hormones’. What do hormones do?”** *Hormones are chemicals that regulate biochemical processes. Many common human processes are started, stopped and moderated by hormones—processes like digestion, metabolism, respiration, tissue function, growth and development, movement and reproduction. Very small quantities of hormone are required in order to be effective. Many hormones are proteins, which includes the anabolic steroids and hemoglobin mentioned in the article. So PEDs are often chemicals that increase the amount of hormone in the body, thereby increasing the desired process like muscle growth or oxygen supply.*

## In-class Activities (lesson ideas, including labs & demonstrations)

1. You might want to have students learn more about how their muscles work via this procedure: <http://www.teachengineering.org/view_lesson.php?url=collection/cub_/lessons/cub_human/cub_human_lesson02.xml>.
2. Although this lab activity is for a biology class, it will be of interest to students studying muscle structure: <https://www.cabrillo.edu/~pdarcey/Bio%2013A/bio13alab/bio13alabs_pdf/13alab_6musc_spr09.pdf>.
3. This set of muscle-related lab activities will give students a better idea of how muscles function. (<https://www.utmb.edu/tstem/nsbri/no_pain_no_gain.pdf>)
4. The chemistry of muscle fatigue is included in this lab activity: <https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&es_th=1&ie=UTF-8#q=muscle+lab+activities&start=10>.
5. The reason that people use PEDs is to improve athletic performance which is dependent on cellular respiration. Students can review their understanding of cellular respiration with this lab from the AP biology curriculum: <http://media.collegeboard.com/digitalServices/pdf/ap/bio-manual/Bio_Lab6-CellularRespiration.pdf>.
6. This lab procedure illustrates Henry’s Law regarding the relationship between pressure and solubility of a gas: <http://chemmovies.unl.edu/chemistry/smallscale/SS038.html>.
7. This two-part lesson plan series from Discovery Education includes activities on performance-enhancing drugs and their effects.
8. Part 1: <http://www.discoveryeducation.com/teachers/free-lesson-plans/thats-dope-part1.cfm> and
9. Part 2: <http://www.discoveryeducation.com/teachers/free-lesson-plans/thats-dope-part2.cfm>.
10. You might consult this lesson plan about the history of PEDs from CTE online and assign each student an athlete or case study to report on in class: <http://www.cteonline.org/portal/default/Curriculum/Viewer/Curriculum?action=2&view=viewer&cmobjid=198213>.
11. A lot of information about the pros and cons of PEDs is contained in this web site. You could create a class debate using this sources as the basis for research. (<http://sportsanddrugs.procon.org/>)

## Out-of-class Activities and Projects (student research, class projects)

1. Students might consult with the school nurse to work as a class on developing an anonymous survey that they give to other students about PED usage in your school.
2. Teams of students might create an awareness campaign about PEDs that they take to students in younger grades in your school district.
3. You might consult this lesson plan about the history of PEDs from CTE online and assign each student an athlete or case study to report on in class. (<http://www.cteonline.org/portal/default/Curriculum/Viewer/Curriculum?action=2&view=viewer&cmobjid=198213>)

## References (non-Web-based information sources)

**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013 and all available Teacher’s Guides, beginning February 1990). 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)**. Scroll to the bottom of the page and click on the *ChemMatters* DVD image at the right of the screen to order or to get more information.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online on the same Web site, above. Simply access the link and click on the “Past Issues” button directly below the “M” in the *ChemMatters* logo at the top of the Web page.**



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Graham, T. Anabolic Steroids: The Downside of Bulking Up. *ChemMatters* **2000**, *18* (2), pp 12–13. This article will provide you with additional background information about anabolic steroids and drug testing for athletes.

Morton, R. Drug Testing at the Olympics—A Team Effort. *ChemMatters* **2000**, *18* (4), pp 7–9. This is another article that will give you background and examples of drug testing. It contains a section on anabolic steroid drugs.

Baxter, R. Sneeze and Wheeze. *ChemMatters* **2006**, *24* (2), pp 7–10. Although this article is about asthma, it contains a significant amount of background material on another type of steroids, corticosteroids.

Tinnesand, M. Your Body under Construction. *ChemMatters* **2011**, *29* (4), pp.14–16. Although this article is about human hormones, it contains a lot of information that will help students understand steroid-based PEDs.

## Web Sites for Additional Information (Web-based information sources)

**More sites on performance-enhancing drugs**

The U.S. Anti-Doping Agency Web site has extensive information on banned substances, testing procedures, science research and many other resources you can consult. It is an excellent source. (<http://sportsanddrugs.procon.org/view.answers.php?questionID=1200>)

The World Anti-Doping Agency (WADA) is a leading authority on PEDs: <https://www.wada-ama.org/>.

This site provides a lot of pro-con perspectives on performance-enhancing drugs: <http://sportsanddrugs.procon.org/view.answers.php?questionID=1200>.

The American Academy of Orthopaedic Surgeons has an extensive Web site on PEDs at <http://www.aaos.org/news/aaosnow/oct08/clinical9.asp>.

How Stuff Works details 10PEDs that are not steroids**. (**<http://science.howstuffworks.com/10-performance-enhancing-drugs.htm>)

**More sites on anabolic** **steroids**

This web site provides infographics about the history of steroid use among athletes: <http://www.weighttraining.com/features/steroids-in-sports>.

This 2014 report from MarketWatch reveals recent trends in PED use among adolescents: <http://www.marketwatch.com/story/national-study-teens-report-higher-use-of-performance-enhancing-substances-2014-07-23>.

From the Mayo Clinic, this site provides some PEDs basics and suggestions on how to help students resist. (<http://www.mayoclinic.org/healthy-living/tween-and-teen-health/in-depth/performance-enhancing-drugs/art-20046620>)

WebMD has created a basic primer on steroid abuse; find it here: <http://www.webmd.com/men/guide/anabolic-steroid-abuse-topic-overview>.

A wealth of information is available via the National Institute on Drug Abuse (NIDA) at <http://www.drugabuse.gov/publications/drugfacts/anabolic-steroids>.

NIDA also has a Web page on steroids, addressed specifically to teens, at <http://teens.drugabuse.gov/drug-facts/anabolic-steroids>.

**More sites on** **blood doping**

WebMD provides blood doping basics at <http://www.webmd.com/fitness-exercise/blood-doping>.

This article, accessed on the National Library of Medicine site, explains the ins and outs of blood doping: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3372716/>.

Linus Pauling studied hemoglobin, and his research provides an interesting backdrop to blood doping: <http://scarc.library.oregonstate.edu/coll/pauling/blood/narrative/page1.html>.

This is a resource from the University of Michigan that helps to explain the science of how oxygen is transported via the blood: <http://www.umich.edu/~projbnb/cvr/O2transport.pdf>.

**More sites on Biogenesis**

Even though this company gets minor mention in the article, the scandal that surrounds it and many of its athlete clients is of some interest.

* Linked here is a series of news stories about the company: <http://www.miaminewtimes.com/specialReports/tony-bosch-and-biogenesis-mlb-steroid-scandal-3698782/>.
* Here is a brief summary of the history of the Biogenesis scandal: <http://www.mlbdailydish.com/2013/2/6/3961640/drugs-and-money-the-biogenesis-scandal-summary>.
* This CSB story recounts allegations that Biogenesis supplied PEDs to adolescents: <http://www.cbssports.com/general/eye-on-sports/22902433/report-biogenesis-clinic-supplied-teens-with-peds>.
* This site contains a recent news update on the scandal: <http://www.masslive.com/sports/index.ssf/2014/08/biogenesis_ped_scandal_clinic.html>.

# The Starting Line of a Drug-Free Athlete

## Background Information (teacher information)

**More on the article**

This is an unusual article for *ChemMatters* in that it does not directly describe a chemistry topic. It can be thought of as a companion article to “Performing Enhancing Drugs: Is Winning Everything?” on page 9 of the October 2014 (this) issue. It describes some of the psychological effects of anabolic steroid use and also recounts the development of two programs aimed at preventing the use of Performance enhancing drugs (PEDs).

It is important for students to understand that there are serious consequences to the use of PEDs. Listing the physical health effects of PED abuse in the Teacher’s Guide to “Performing Enhancing Drugs: Is Winning Everything?” is one thing, but reading about the death of a high school student and the actions of adults to prevent other deaths is something else. So this article plays an important role in giving students the overall picture.

In this brief Teacher’s Guide we will focus on some of the reasons for PED abuse, the non-physiological effects, treatments for abuse and the ATLAS/ATHENA abuse prevention program.

**More on anabolic steroid abuse**

The article describes the story of one young man’s abuse of anabolic steroids, but how widespread is the problem? A recent report from MarketWatch online in 2014 reported increasing numbers of adolescents using steroids and human growth hormone:

NEW YORK, July 23, 2014 New, nationally projectable survey results released today by the [Partnership for Drug-Free Kids](http://www.drugfree.org/) confirmed a significant increase – a doubling – in the reported lifetime use of synthetic human growth hormone (hGH) among teens. According to the latest Partnership Attitude Tracking Study (PATS), sponsored by [MetLife Foundation](http://www.metlife.org/),11 percent of teens in grades 9-12 reported "ever having used" synthetic human growth hormone without a prescription, up dramatically from just 5 percent in 2012.

These findings underscore teens' growing interest in performance enhancing substances, as well as the need for tighter regulation and more accurate labeling of "fitness-enhancing" over-the-counter products implying they contain synthetic hGH.

. . . African-American and Hispanic teens are more likely to report use of synthetic hGH, with 15 percent of African-American teens, 13 percent of Hispanic teens and 9 percent of Caucasian teens saying they used synthetic hGH at least once within their lifetime. Both boys and girls report use of synthetic human growth hormone and steroids without a prescription. The PATS study found no significant difference between the proportions of teen boys vs. teen girls, who report using synthetic hGH (12 percent vs. 9 percent, respectively).

In addition to the reported increase in teen use of synthetic hGH, PATS confirms a gradual, long-term increase in teens' reported lifetime use of steroids. Steroid use among teens has increased from 5 percent in 2009 to 7 percent in 2013. The PATS data show a strong correlation between the use of synthetic hGH and steroids. Currently, one in five teens (21 percent) reports that at least one friend uses steroids, and another one in five teens (21 percent) believes it is easy to obtain steroids. Both of these measures improved in 2010 and have since remained consistent.

(<http://www.marketwatch.com/story/national-study-teens-report-higher-use-of-performance-enhancing-substances-2014-07-23>)

Knowing the scope of abuse of performance-enhancing drugs leads us to ask why adolescents—athletes and non-athletes—would consider using steroids or hGH or blood doping drugs. The frequently cited major reasons include improving athletic performance, as in the case of Efrain Marrero in the article and improving body image. A third reason is to increase muscle mass or reduce body fat. Many individuals who use steroids for this reason suffer from muscle dysmorphia, which is mentioned in the Performance-Enhancing Drugs article in this edition. Dysmorphia is a behavioral syndrome which causes individuals to have a distorted image of their bodies.

There is also evidence to suggest that some adolescents abuse steroids as part of a pattern of high-risk behaviors such as drinking and driving, carrying a gun and abusing other illegal drugs. And many of these teenagers also have a history of physical or sexual abuse. The research suggests an associative connection between many of these symptoms rather than a causal relationship with steroid abuse.

Forbes Magazine (online) reported on a survey conducted in 2013, by Digital Citizens Alliance, a group advocating for a safer internet, about opinions regarding PEDs:

As Major League Baseball announces the suspension of former Most Valuable Player Ryan Braun, a survey by the Digital Citizens Alliance (a consumer-oriented group focused on making the Internet a safer place) found that nearly half of males aged 18-25 thought that taking PEDs was critical to making it in professional sports or enhancing one’s athletic performance.

More than three-quarters of both young males and parents in our survey said that pro athletes using PEDs has put pressure on young athletes to use drugs as well. And 58 percent of these young males thought that at least one-third of the major leaguers on the rosters in last week’s All-Star Game had used PEDs.

(<http://www.forbes.com/sites/bobcook/2013/07/30/does-pro-ped-use-put-pressure-on-young-athletes-to-do-the-same-surveys-say-yes/>)

Survey results like this one suggest that the use of PEDs by high-profile professional athletes also contributes to younger athletes at least thinking about using PEDs themselves if not actually using them.

**More on** **the effects of anabolic steroids**

The Teacher’s Guide for the article “Performing Enhancing Drugs: Is Winning Everything?” on page 9 of this issue describes many of the physiological effects and side-effects of abusing various performance enhancing drugs. In this section of this Teacher’s Guide we will review some of the psychological effects.

Recall that the article describes the depression and paranoia that Efrain Marrero experienced when he stopped taking steroids. And the article sadly notes that he took his own life only weeks after he quit steroids. As we will see, abusing PEDs has psychological implications while the drugs are being used and even afterwards.

One of the major effects is increased anger and aggression. Popular articles about PEDs often highlight what has come to be known as “roid rage.” Case studies and research confirm that using higher doses of anabolic steroids increases irritability, anger and aggression in the form of fighting, armed robbery and vandalism. The chemistry alone should lead us in that direction since many PEDs are hormones by biochemical nature, and many hormones affect mood.

It should be noted that the results of a limited number of controlled studies on steroids and aggression have not shown a clear causal relationship. More studies are warranted. According to the National Institutes of Health’s National Institute on Drug Abuse:

Scientists have attempted to test the association between anabolic steroids and aggression by administering high steroid doses or placebo for days or weeks to human volunteers and then asking the people to report on their behavioral symptoms. To date, four such studies have been conducted. In three, high steroid doses did produce greater feelings of irritability and aggression than did placebo, although the effects appear to be highly variable across individuals. In one study, the drugs did not have that effect. One possible explanation, according to the researchers, is that some but not all anabolic steroids increase irritability and aggression. Recent animal studies show an increase in aggression after steroid administration.

In a few controlled studies, aggression or adverse, overt behaviors resulting from the administration of anabolic steroid use have been reported by a minority of volunteers.

In summary, the extent to which steroid abuse contributes to violence and behavioral disorders is unknown. As with the health complications of steroid abuse, the prevalence of extreme cases of violence and behavioral disorders seems to be low, but it may be underreported or underrecognized.

Research also indicates that some users might turn to other drugs to alleviate some of the negative effects of anabolic steroids. For example, a study of 227 men admitted in 1999 to a private treatment center for addiction to heroin or other opioids found that 9.3 percent had abused anabolic steroids before trying any other illicit drug. Of these 9.3 percent, 86 percent first used opioids to counteract insomnia and irritability resulting from anabolic steroids.

(<http://www.drugabuse.gov/publications/research-reports/anabolic-steroid-abuse/what-effects-do-anabolic-steroids-have-behavior>)

Research has also shown that steroid abuse does have implication for the brain. Many drugs of abuse affect the central nervous system directly to produce the “high” that many users seek, but steroids do not. However, since high-dose steroid abuse does affect mood, it is reasonable to suspect that long-term abuse may well involve some of the same central nervous pathways involving dopamine and serotonin, both of which have significant mood effects. Many steroids abusers are, in fact, subject to extreme mood swings, so the drugs definitely affect the brain.

A 2005 review in [the journal] *CNS Drugs* concluded that steroid abuse was associated with significant psychiatric symptoms such as aggression, mania and violence. Suicide and psychosis occur less often, but they are also associated with steroid abuse. The recreational use of anabolic steroids also carries the risk of causing damage to neurons that may be irreversible. Additional symptoms of recreational steroid use include mood disorders and other types of drug abuse, although these effects are poorly studied as of 2013.

(<http://www.recovery.org/topics/choosing-the-best-inpatient-steroids-recovery-center/>)

As to the question of whether steroids are addicting, the National Institute on Drug Abuse says this:

Even though anabolic steroids do not cause the same high as other drugs, steroids are reinforcing and can lead to addiction. Studies have shown that animals will self-administer steroids when given the opportunity, just as they do with other addictive drugs. People may persist in abusing steroids despite physical problems and negative effects on social relationships, reflecting these drugs’ addictive potential. Also, steroid abusers typically spend large amounts of time and money obtaining the drug—another indication of addiction.

Individuals who abuse steroids can experience withdrawal symptoms when they stop taking them—including mood swings, fatigue, restlessness, loss of appetite, insomnia, reduced sex drive, and steroid cravings, all of which may contribute to continued abuse. One of the most dangerous withdrawal symptoms is depression—when persistent, it can sometimes lead to suicide attempts. Research has found that some steroid abusers turn to other drugs such as opioids to counteract the negative effects of steroids.

(<http://www.drugabuse.gov/publications/drugfacts/anabolic-steroids>)

We can see, then, that abusing steroids and other PEDs has both physical and psychological effects, some short-term, some longer-term.

**More on** **treatment**

The article briefly describes the treatment offered to Efrain Marrero. And while most of the article is about efforts to *prevent* PEDs abuse, it is worth looking at possible treatments.

Many steroid abusers never seek treatment of any kind, physical or psychological. There is a belief among users that their physicians know very little about steroid use. In fact, in one study, abusers reported trusting information from their dealers more than their doctors. Rarely do steroid abusers seek treatment for dependence. So treatment methods are not well documented and are based on the experiences of relatively few physicians who treat steroid abusers regularly.

Abusers who do seek treatment usually go through a detoxification process which involves a tapering off of use under the supervision of an endocrinologist who can monitor hormone changes carefully. As steroid dosage is reduced, patients may experience withdrawal symptoms, including abdominal pain, reduced appetite, fatigue and weakness. The National Library of Medicine (online) published a summary of withdrawal treatments:

Anabolic-androgenic steroid (AAS) withdrawal is established to be an important, though poorly known medical problem, because of AAS potency to cause physical and psychological dependence. Thus discontinuation of high-dose, long-term anabolic steroid use, apart from endocrine dysfunction (hypogonadotropic hypogonadism), may lead to development of withdrawal symptoms. They include mood disorders (with suicidal depression as the most life-threatening complication), insomnia, anorexia, decreased libido, fatigue, headache, muscle and joint pain, and desire to take more steroids. The withdrawal from anabolic steroids usually requires treatment. Clinical management, as with other drugs of abuse, consists of supportive therapy and pharmacotherapy. The goals of treatment are to restore endocrine (hypothalamic-pituitary-gonadal, HPG) function and to alleviate withdrawal symptoms. The endocrine medications that are targeted specifically to ameliorate HPG function include testosterone esters, human chorionic gonadotropin, synthetic analogues of gonadotropin-releasing hormone and antiestrogens. They are indicated in the presence of persistent clinical symptoms or/and laboratory evidence of HPG dysfunction. Other medications that are targeted to provide symptomatic relief include antidepressants (especially serotonin selective re-uptake inhibitors), nonsteroidal anti-inflammatory drugs and clonidine. Notwithstanding, it should be remembered that many of the above mentioned drugs have their own potential for abuse or side-effects, so their use must be carefully weighted and optimal treatment strategies for AAS withdrawal must await further clinical research.

(<http://www.ncbi.nlm.nih.gov/pubmed/11899857>)

One possible side effect in this phase of treatment, as noted in the above report, is depression. The second phase of treatment may include a 12-step program or cognitive behavioral therapy which is aimed at discovering underlying reasons for abusing drugs and recommending coping mechanisms in case of relapse.

Some medications that have been used for treating steroid withdrawal restore the hormonal system after its disruption by steroid abuse. Other medications target specific withdrawal symptoms—for example, antidepressants to treat depression and analgesics for headaches and muscle and joint pains.

**More on prevention**

Steroid prevention generally takes one of two forms—enforcement of regulations banning the use of steroids and educational programs like ATLAS/ATHENA.

Drug testing programs among the major U.S. sports leagues and the Olympics have garnered a lot of attention over the last thirty years. High-profile stars have been accused of using banned substances and many of them have served suspensions. At the college level the NCAA’s list of banned substances includes anabolic agents, beta-2 agonists, diuretics and other masking agents and blood doping. From the NCAA web site:

The NCAA shares the responsibility of promoting a drug-free athletics environment with its member institutions to protect the health of student-athletes and preserve fair competition.

Drug testing in the NCAA began in 1986 when testing at championship events began, and it expanded to a year-round program in Divisions I and II in 1990. Today, 90 percent of Division I, 65 percent of Division II and 21 percent of Division III schools conduct their own drug-testing programs in addition to the NCAA’s.

Approximately $4.5 million is invested each year to collect and analyze approximately 13,500 samples through the NCAA’s national drug-testing program, and more than $1.5 million is provided each year to assist drug-education programs at its member colleges and universities.

NCAA drug-test samples are collected and processed by an independent certified collection agency. The samples are collected and analyzed under a strict, published protocol using laboratories certified by the World Anti-Doping Agency, which establishes Olympic anti-doping policies.

(<http://www.ncaa.org/health-and-safety/policy/2013-14-ncaa-banned-drugs>)

At all levels of sports competition, testing programs have specific provisions for how athletes are selected for testing, how samples are obtained, how samples are tested in the laboratory and how results are reported. Typically testing samples are obtained either by taking a urine sample or a blood sample. With witnesses present, the samples are placed in tamper-proof containers and transferred to a licensed testing lab. The standard testing process is accomplished using a gas chromatograph to separate components and then a mass spectrograph for identifying components. You can read about U.S. Anti-doping Agency procedures here: <http://www.usada.org/testing/sample-collection-process/>, and NCAA testing procedures here: <http://www.ncaa.org/health-and-safety/policy/drug-testing>.

At the K-12 school level a minority of school districts in the United States have drug testing programs. Estimates range from 4% to 14%. Even less certain is the number of schools that test specifically for steroids. In most cases, steroids and other performance enhancing drugs are not part of the drug testing panel, and, therefore, testing for them would add to the total cost. Although drug testing in public schools has been upheld by the U.S. Supreme Court in 1995 and again in 2002, most schools do not test, primarily due to the cost. Standard student drug tests using urine samples may cost as much as $50 per student with steroid testing extra. Only three states—Texas, Illinois and New Jersey tested students for steroids as of 2011.

In addition, multiple research studies have little or no correlation between drug testing and reduced rates of drug use among students. See the Institute of Education Science web site for more information: <http://ies.ed.gov/ncee/pubs/20104025/>. You can access more information about school drug testing on the U. S. National Institute on Drug Abuse web site: <http://www.drugabuse.gov/related-topics/drug-testing/faq-drug-testing-in-schools>.

**More on ATLAS and ATHENA**

As the article describes, the program titled Adolescents Training and Learning to Avoid Steroids (ATLAS) is a program for male high school athletes and is designed to prevent abuse of anabolic steroids and other drugs common to the high school culture. The program was developed in 1994, by two physicians, Linn Goldberg and Diane Elliot, of the Division of Health Promotion & Sports Medicine at the Oregon Health and Science University in Portland, Oregon.

The purpose of the program is described in the coach’s manual for the ATLAS program:

ATLAS emphasizes prevention of ‘steroid’ use, because of its strong connection to sports. However, ATLAS also targets alcohol and other drugs. ATLAS focuses on 1) the consequences of drug and athletic supplement use, 2) body image perception, 3) practicing how to refuse a drug offer, 4) media awareness, and 5) sports nutrition and strength training as alternatives to performance enhancing drugs.

(<http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/upload/Coach-Manual-ATLAS.pdf>)

In a given school, individual teams are recruited to participate during their season because that is when most athletes are at greatest risk to abuse steroids. One of the key elements of the ATLAS program is the fact that student leaders from the team are trained facilitators under the supervision of a coach of the team. The ATLAS web site summarizes how the program works:

A coach and selected student athletes called “Squad Leaders” lead the program. The program materials are completely scripted and easy to follow. Little or no preparation is needed. There are 10 sessions for ATLAS. Each session lasts 45 minutes. Sessions are typically scheduled once per week during the season on a “light” practice day. Coaches facilitate the program, keep athletes on task, and introduce and wrap up student-led activities. Squad Leaders provide a majority of the instruction for their small group of teammates. Sessions include role-plays, student-created campaigns or public service announcements and instructional, interactive games.

(<http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/atlas.cfm>)

There are ten sessions in the program. Each session lasts 45-50 minutes and focuses on a different aspect of the issue. Participating athletes engage in interactive activities during each session. For example, in Lesson 1 the point is made that anabolic steroids are often taken in order to build muscle mass. One activity in the lesson gives athletes an alternative to taking steroids. The lesson emphasizes the importance of eating foods that contain proteins since it is proteins that build muscle tissue. Athletes are asked to rank an array of foods that contain protein in order of their protein content. The lesson also tells athletes that it is carbohydrate foods that provide workout energy. Other topics include steroids in sports, the media, strength training, goals setting and refusal skills.

Is the program effective? Program evaluations done in 1996, soon after the program began, report that one year after completing the program, athletes had half the incidence of new steroid abuse compared to a control group. These same athletes reported less abuse of other drugs like alcohol and marijuana and less risk-taking behaviors.

The ATLAS web site reports that:

More than 3,200 high school athletes participated in the ATLAS research studies through a 5-year grant from the National Institute on Drug Abuse at the National Institutes of Health. The results of ATLAS have been published in prestigious medical journals, including the Journal of the American Medical Association and the Archives of Pediatrics & Adolescent Medicine. ATLAS and ATHENA (its ‘sister’ program for young women athletes) are the only effective drug use prevention programs listed by the Anabolic Steroid Control Act, passed by Congress and signed into federal law in 2004.

(<http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/upload/Coach-Manual-ATLAS.pdf>)

The female version of ATLAS is called Athletes Targeting Healthy Exercise and Nutrition Alternatives or ATHENA. The program is organized very much like ATLAS but with some variation in topics covered. Some of the topics unique to ATHENA are adolescent body changes, Title IX awareness and menstrual cycles. There are eight sessions in ATHENA.

When ATHENA athletes are compared to control group athletes, the control athletes were three times more likely to use diet pills during their sport season and twice as likely to use other substances that can shape their bodies. ATEHA athletes were also much less likely to engage in risky behaviors.

The article mentions the Efrain Marrero Foundation that was established by Efrain’s parents after his death. The vision of the foundation, as stated on its Web site is:

* Educating students, parents, teachers, coaches, athletic directors, and trainers about the devastating consequences of steroid abuse
* Fostering an environment where our youth compete, and are evaluated using only their natural abilities
* Providing a nationwide network of resources for parents and children dealing with steroid abuse
* Staying culturally relevant through education and awareness

(<http://www.nosteroids.org/about.htm>)

The foundation trains speakers to go into schools and other community groups and it also has produced videos about steroid abuse. It sponsors radio and TV ads as well as other media releases. As the article states, the Foundation is a partner of the ATLAS and ATHENA programs.

## Connections to Chemistry Concepts (for correlation to course curriculum)

**Chemistry and Personal Health—**The focus of this article is not on chemistry but rather on the way in which use and abuse of chemical substances can affect human health.

## Possible Student Misconceptions (to aid teacher in addressing misconceptions)

“**Steroids aren’t addicting and I can stop taking them any time.”** *Two responses to this are appropriate. Steroids can be addicting depending on the dose. And it is possible to stop taking steroids at any time, but as the article states, the results of cessation without supervised tapering can be paranoia, depression and possible suicidal thoughts. See “More on the effects of anabolic steroids” above for additional details*.

## Anticipating Student Questions (answers to questions students might ask in class)

**“Could we have these programs at our school?”** *Yes. You can get more information by calling 503-418-4166, or emailing* [*chpr@ohsu.edu*](mailto:chpr@ohsu.edu)*. Your school can order materials here:* [*http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/atlas-and-athena-program.cfm*](http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/atlas-and-athena-program.cfm)*.*

## In-class Activities (lesson ideas, including labs & demonstrations)

If students are interested in bringing the ATLAS or ATHENA program to your school, you can have a student contact the University of Oregon for information at 503-418-4166 or  
[chpr@ohsu.edu](mailto:chpr@ohsu.edu).

## References (non-Web-based information sources)



**30 Years of *ChemMatters***

Available Now!

**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013 and all available Teacher’s Guides, beginning February 1990). 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)**. Scroll about half way down the page and click on the *ChemMatters* DVD image at the right of the screen to order or to get more information.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online on the same Web site, above. Simply access the link and click on the “Past Issues” button directly below the “M” in the *ChemMatters* logo at the top of the Web page.**

Graham, T. Anabolic Steroids: The Downside of Bulking Up. *ChemMatters* **2000**, *18* (2), pp 12–13. This article will provide you with additional background information about anabolic steroids and drug testing for athletes

Morton, R. Drug Testing at the Olympics—A Team Effort. *ChemMatters* **2000**, *18* (4), pp 7–9. This is another article that will give you background and examples of drug testing. It contains a section on anabolic steroid drugs.

Baxter, R. Sneeze and Wheeze. *ChemMatters* **2006**, *24* (2), pp 7–10. Although this article is about asthma, it contains a significant amount of background material on another type of steroids, corticosteroids.

Tinnesand, M. Your Body under Construction, *ChemMatters* **2011**, *29* (4), pp 14–16. Although this article is about human hormones, it contains a lot of information that will help students understand steroid-based PEDs.

Wendel, J. Performing Enhancing Drugs—Is Winning Everything? *ChemMatters* **2014**, *32* (3), pp 9–11. This article exams the abuse of steroids and other performance enhancing drugs and their effects. It references ATLAS and ATHENA.

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The three publications below were originally published in printed journals but are now accessible on the ATLAS Web site at <http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/atlas-research-findings.cfm>.

Goldberg, Linn, David McKinnon, Diane Elliot, et al. The Adolescents Training and Learning to Avoid Steroids Program: Preventing Drug Use and Promoting Health Behaviors. *Archives of Pediatric and Adolescent Medicine* 2000, *154*, pp 332–338.

Goldberg, Linn, Diane Elliot, Greg Clarke, et al. Effects of a Multidimensional Anabolic Steroid Prevention Intervention: The Adolescent Training and Learning to Avoid Steroids (ATLAS) Program. *Journal of the American Medical Association* 1996a, *276*, pp 1555–1563.

Goldberg, Linn, Diane Elliott, Greg Clarke, et al. The Adolescents Training and Learning to Avoid Steroids (ATLAS) Prevention Program: Background and Results of a Model Intervention. *Archives of Pediatric and Adolescent Medicine* 1996b, *150*, pp 713–721.

## Web Sites for Additional Information (Web-based information sources)

**More sites on** **treatment**

This Cleveland Clinic article details many of the psychiatric effects of steroid abuse:<http://www.ccjm.org/content/74/5/341.full.pdf+html>.

This article is cataloged in the National Library of Medicine and gives detailed information on treatment methods for steroid abuse: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2875348/>.

From the U.S. Department of Health and Human Services’ Substance Abuse and Mental Health Administration comes this pamphlet on treatment of steroid abuse: <http://store.samhsa.gov/shin/content/MS991/MS991.pdf>.

This article from The School Administrator (online) highlights several school districts’ effort to test for steroids: <http://www.aasa.org/SchoolAdministratorArticle.aspx?id=8104>.

The National Institute of Drug Abuse published a summary of drug testing issues online at <http://www.drugabuse.gov/related-topics/drug-testing/faq-drug-testing-in-schools>.

The NCCA Web site on banned and restricted substances is found here: <http://www.ncaa.org/health-and-safety/policy/drug-testing>.

**More sites on** **ATLAS and ATHENA**

The home page of the ATLAS program gives a basic description, research findings and program materials. (<http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/atlas.cfm>)

A sample section for Lesson 1 of the coach’s manual for the ATLAS program can be found here: <http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/upload/Coach-Manual-ATLAS.pdf>.

The ATHENA home page provides information similar to that of ATLAS: [www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/athena.cfm](http://www.ohsu.edu/xd/education/schools/school-of-medicine/departments/clinical-departments/medicine/divisions/hpsm/research/athena.cfm).

The Substances Abuse and Mental Health Services Administration evaluates substance abuse programs and calls ATLAS/ATHENA a model program. (<http://www.samhsa.gov/SAMHSA_news/VolumeXI_1/article6.htm>)

The National Institute on Drug Abuse features ATLAS/ATHENA: <http://www.drugabuse.gov/publications/research-reports/anabolic-steroid-abuse/nida-funded-prevention-research-helps-reduce-steroid-abuse>.

The Efrain Marrero Foundation, as the article describes, was set up after his death to provide information and support for programs that aim to prevent steroid substance abuse. Here’s the link to the site: <http://www.nosteroids.org/steroids.htm>.

# Do You Know about BVO?

## Background Information (teacher information)

**More on** **bromine-containing products used in non-soda products**

The issue about brominated vegetable oil (BVO) and its safety as a food additive is dependent upon long term studies on the effect of BVO in humans. These long term studies on humans have not been done by the FDA or other groups such as the Flavor Extract Manufacturing Association (FEMA). The FDA is not required to do such studies—rather food manufacturers are responsible, submitting their research data to the FDA for evaluation. The first study about BVO was done on rats in 1969 and showed cardiotoxicity at high doses. This was the basis for the FDA in 1970 to remove BVO from the “generally recognized as safe” category (GRAS). Six months later, BVO was allowed to be used in doses not to exceed 15 parts per million (ppm). BVO has been sitting on an FDA list of safe food additives on an interim basis ever since. The list includes things like saccharin, mannitol, and acrylonitrile copolymers. The FDA’s response to the concerns about BVO is that the additive is safe if it does not exceed the recommended maximum dose of 15 (ppm). Since the FDA determines what needs to be evaluated, based on risk assessments, the agency has concluded it has other priorities than re-evaluating BVO. And the agency says that BVO is not in regulatory limbo. For a summary discussion about the issue of BVO safety and the FDA’s involvement, refer to the following website: [http://www.foodnavigator-usa.com/Regulation/FDA-Brominated-vegetable-oil-BVO-is-safe-so-removing-its-interim-status-is-not-a-priority](http://www.foodnavigator-usa.com/Regulation/FDA-Brominated-vegetable-oil-BVO-is-safe-so-removing-its-interim-status-is-not-a-priority?utm_source=copyright&utm_medium=OnSite&utm_campaign=copyright).

The key issue with regard to the safety of bromine, in whatever compound it is found, is the extent to which it builds up in the tissue (particularly fat tissue) and what long term effect this chemical buildup has on humans. Excessive exposure to bromine in various compounds does create some health issues. Negative effects of bromine on human physiology have been determined as much by anecdotal evidence as long term studies.

But before getting into that subject, bromine in various compounds continues to serve a variety of purposes, chemically speaking. In its simplest form, potassium bromide, KBr, is used in veterinary medicine to treat epilepsy in dogs. The presence of bromine in the body is necessary for tissue development. Also in our bodies, an anti-parasitic enzyme preferentially uses bromine rather than chlorine in the immune system. Our body’s eosinophils (specialized white blood cells) use the bromine in the presence of hydrogen peroxide as an enzyme (a peroxidase) to kill a variety of parasitic worms as well as certain bacteria, including the tuberculosis bacterium.

Many active ingredients in over-the-counter or prescription drugs contain bromine. Many others rely on brominated intermediates during their manufacture. One example is the general anesthetic, halothane, which contains a bromine atom in its chemical structure. Naproxen, a new analgesic, utilizes a brominated intermediate in its manufacture. The antihistamine, bromopheniramine maleate, and the cough medicine, dextromethorphan hydrobromide, also utilize bromine in their make-up. And several drugs that treat pneumonia and cocaine addiction contain bromine. Bromhexine improves the performance of amoxicillin in the treatment of pneumonia. Bromocriptine is effective in the treatment of cocaine addiction. Research continues with a brominated drug, 1-bromogalanthamine, being developed for potential use in treating Alzheimer's disease. Several other bromine-containing drugs are being studied for their use in treating cancer and AIDS.

Other brominated products are used as fumigants, flame proofing agents, water purification compounds, dyes and sanitizers, and inorganic bromides are still used in photography.

The use of brominated compounds to control insects indirectly illustrates why brominated compounds were taken out of sedatives years ago—because they adversely affect the nervous system when used excessively or long term. An insecticide such as methyl bromide interferes with the function of an insect’s nervous system. These bromides are highly effective soil fumigants and are also used to fumigate grain in storage. Bromine-containing compounds are used in swimming pools and industrial cooling towers to control algae, bacteria, and odors.

**More on** **bromine-containing products**

As mentioned, bromine is a useful component of both pesticides, water purification and, of course, in drugs. Information on safety and levels of tolerance for bromine is found at <http://www.epa.gov/oppsrrd1/REDs/old_reds/bromine.pdf> and <http://www.epa.gov/oppsrrd1/REDs/factsheets/4015fact.pdf>.

Bromine in the form of bromides (KBr, NaBr) has a long history of use as a diuretic, antiepileptic and sedative. The human health effects of these compounds are well known. Bromides depress the central nervous system when taken daily at a level of 1–2 grams per day. Their effect is slowly reversed when dosing is stopped. Bromide has a half-life of about 12 days in the human body.

Doses of 1.9 to 2.9 grams per day given to patients over a four month period did not induce signs of bromide intoxication. A moderate amount of bromide to treat epilepsy is 50 mg per kg of body weight. The lowest levels from oral ingestion of bromides (in water) resulting in bromide intoxication is 100 mg/dl (of blood) but signs of intoxication may not appear even when blood levels are over 200 mg/dl. Compare that with the upper limit allowed by the FDA for bromine, in the form of BVO, of 15 ppm in soda and other drinks that contain BVO! But again, the concern is the cumulative effect of ingesting bromine.

Bromine is used in flame retardants, which saw an increased use in the early 1970s in flammable materials, such as plastics and synthetic fibers, which became more abundant in various products, including furniture and electronics, among other things. Some examples of the main commercial brominated flame retardants (BFRs) are:

* TBBPA: Tetrabromobiphenol-A
* HBCD: Hexabromocyclododecane
* Deca-BDE: Decabromodiphenylether

Brominated flame retardants make ignition more difficult in the first place. With combustion occurring, the retardants suppress the combustion process through the release of bromine atoms into the gas phase of a fire as the retardant-containing material burns. These bromine atoms (in the gaseous phase) “interfere” with the combustion process by displacing oxygen molecules needed for combustion. Reducing the amount of oxygen available reduces the intensity (rate) of the combustion process, lowering the temperature which, in turn, reduces the combustion rate because lower temperatures mean fewer fuel particles released in the gaseous phase. The bromine containing fire retardants also increase the amount of charring, which further reduces the combustion rate since the charred surface decreases access at the combustion surface to the air needed for burning.

(<http://www.bsef.com/bromine-fire-safety-infosheet>)

**More on bromine effects on health**

Studies on flame retardants that contain bromine show that the buildup of these chemicals in the body disrupts hormone function, in particular, the thyroid-stimulating hormone, TSH. This in turn may interfere with the functioning of the thyroid, which is responsible for secreting the hormone, thyroxin, which controls cellular metabolism. Government studies show that, although bromine competes with iodine in the synthesis of thyroxin, if iodine concentration in the blood is greater than bromine, iodine “wins out” in terms of its uptake by the thyroid gland. In addition, even if bromine levels in the blood are higher than iodine, there is an increase in the secretion of TSH (from the pituitary gland in the brain) as a response to lowered levels of iodine (feedback response). So this counters any reduction in thyroxin production by the thyroid gland.

Potassium bromate (KBrO3) is a food additive, particularly in wheat flour. Its negative effects on health are not known directly. It is listed as a Class 2B carcinogen, which means its effects have been determined in lab animals (rats) only. Studies have not been done with feeding brominated flour products to animals, just the feeding orally of potassium bromate. Potassium bromate has been used in the US baking industry since 1914. Its function in bread-making is to increase the elasticity of the dough by strengthening its network of molecular bridges, which results in the formation of tiny, thin-walled bubbles as the bread rises.

The making of “clumped” bread dough is accomplished by increasing the number of gluten bonds between dough “particles”. This is done by oxidation through the reaction of potassium bromate with the dough ingredients. Without the bromate, the dough formation would depend on oxygen worked into the dough by the kneading of the bread. The bromate, through oxidation, speeds up the process, producing a better rising of the dough. The gluten is the glue that binds, literally!

In the baking process, the unreacted bromate is converted to harmless potassium bromide. That there is some unreacted potassium bromate in the range of 20 parts per billion or less is acceptable to the FDA. Yet brominated flour products are banned in Canada, Europe, Brazil, and China, among other countries. Ascorbic acid is a recommended substitute for potassium bromate. The FDA suggests that the flour industry not include the bromate in its products, but it is a voluntary action by the industry.

**More on** **drinking soda**

Although the *ChemMatters* article is about brominated vegetable oil (BVO) as an additive in soda, there are probably fewer issues with that ingredient in soda than with sugar substances in drinks and the extent to which people consume soda, both the diet variety as well as the regularly sweetened variety. The obesity epidemic is very much tied to the overconsumption of calories, including those found in sugary drinks. Soft drinks are considered a significant part of the American diet. The beverage industry is an $80 billion per year business with some $64 billion spent by people on carbonated soft drinks. Regular soda accounts for about 73% of sales, diet soda about 27%.

Current medical studies suggest that the high level consumption of sugar is possibly more detrimental to our health than fat in our diet. The rise of diabetes Type 2 in children and adults may very well be attributed to the excess of sugar in the diet and its effect on the overstimulation of insulin secretion which in turn increases the sense of hunger and more food (calorie) consumption! So one could make the argument that people should be much more concerned about the overconsumption of soda and its sugar content than about the presence of BVO, if there is still such in soda these days. Actually, there is still BVO in Mountain Dew®, Squirt®, Fanta Orange, Sunkist Pineapple, Gatorade Thirst Quencher Orange, Powerade Strawberry Lemonade and Fresca Original Citrus. As a generalization, the following are typical ingredients in soda:

Carbonated Water

Fructose corn syrup or sucrose

Caramel color

Phosphoric acid

Natural flavors

Caffeine

Citric acid

Sodium citrate

Sodium benzoate

Modified food starch

Ester gum

Red 40

Yellow 5

Malic acid

The following chart lists a variety of beverages and calorie content: (note that orange juice contains more calories than soda!)

|  |  |  |
| --- | --- | --- |
| **Beverage** | **Serving Size** | **\*Calories** |
| Soda | 12 ounces | 124-189 |
| Diet soda | 12 ounces | 0-7 |
| Bottled sweet tea | 12 ounces | 129-143 |
| Brewed tea, unsweetened | 12 ounces | 4 |
| Orange juice, unsweetened | 12 ounces | 157-168 |
| Apple juice, unsweetened | 12 ounces | 169-175 |
| Tomato/Vegetable juice | 12 ounces | 80 |
| Cranberry juice cocktail | 12 ounces | 205 |
| Whole Milk | 12 ounces | 220 |
| 2% low-fat milk | 12 ounces | 183 |
| 1% low-fat milk | 12 ounces | 154 |
| Nonfat milk | 12 ounces | 125 |
| Soy milk | 12 ounces | 147-191 |
| Coffee, black | 12 ounces | 0-4 |
| Coffee with cream (2 tablespoons half and half) | 12 ounces | 39-43 |
| Coffee with whipped cream (2 tablespoons from can) | 12 ounces | 15-19 |
| Coffee with heavy whipping cream (2 tablespoons) | 12 ounces | 104-108 |
| Caffe Latte, whole milk (Starbucks) | 12 ounces | 200 |
| Caffe Latte, nonfat (Starbucks) | 12 ounces | 120 |
| Sports drink (like Gatorade) | 12 ounces | 94 |
| Energy drink (like Red Bull) | 12 ounces | 160 |
| Beer | 12 ounces | 153 |
| Red wine | 5 ounces | 125 |
| White wine | 5 ounces | 122 |
| Hard liquor (vodka, rum, whiskey, gin; 80 proof) | 1.5 ounces | 96 |

(<http://www.webmd.com/diet/calories-in-drinks-and-popular-beverages> )

Associated with the presence of sugar in soda and other sweetened drinks is the issue of the kinds of sweeteners, in particular, high fructose corn syrup (HFCS). The debate rages on over just what deleterious effect HFCS has on the body, and, in particular, on the liver. The scientific data is conflicting since it is hard to carry out studies on humans.

A causal role of fructose intake in the etiology of the global obesity epidemic has been proposed in recent years. This proposition, however, rests on controversial interpretations of two distinct lines of research. On one hand, in mechanistic intervention studies, detrimental metabolic effects have been observed after excessive isolated fructose intakes in animals and human subjects. On the other hand, food disappearance data indicate that fructose consumption from added sugars has increased over the past decades and paralleled the increase in obesity. Both lines of research are presently insufficient to demonstrate a causal role of fructose in metabolic diseases, however. Most mechanistic intervention studies were performed on subjects fed large amounts of pure fructose, while fructose is ordinarily ingested together with glucose. The use of food disappearance data does not accurately reflect food consumption, and hence cannot be used as evidence of a causal link between fructose intake and obesity. Based on a thorough review of the literature, we demonstrate that fructose, as commonly consumed in mixed carbohydrate sources, does not exert specific metabolic effects that can account for an increase in body weight. Consequently, public health recommendations and policies aiming at reducing fructose consumption only, without additional diet and lifestyle targets, would be disputable and impractical. Although the available evidence indicates that the consumption of sugar-sweetened beverages is associated with body-weight gain, and it may be that fructose is among the main constituents of these beverages, energy overconsumption is much more important to consider in terms of the obesity epidemic.

(<http://journals.cambridge.org/action/displayFulltext?type=6&fid=9212194&jid=NRR&volumeId=-1&issueId=-1&aid=9212193&bodyId=&membershipNumber=&societyETOCSession=&fulltextType=RA&fileId=S0954422414000067#cjotab_>)

Refer to complementary articles on the issue of reliable statistical research studying the relationship between consuming sugary soda drinks and obesity: <http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=2943452&fileId=S0954422408110976> and <http://earthsky.org/human-world/a-brief-history-of-high-fructose-corn-syrup>.

**More on sugar and obesity**

Since many drinks, including soda, contain a number of sweeteners, both sugar based and synthetic types, it is necessary to look at the relationship between consuming these sweeteners and obesity, as well as the development of Type 2 diabetes. In some respects, these health issues may be of more importance than the effects of low levels of bromine in the human body. According to the Harvard School of Public Health, two out of three adults and one out of three children are overweight or obese. The US spends an estimated $190 billion per year to treat obesity-related health conditions. Much of this obesity can be attributed to the consumption of sugary drinks.

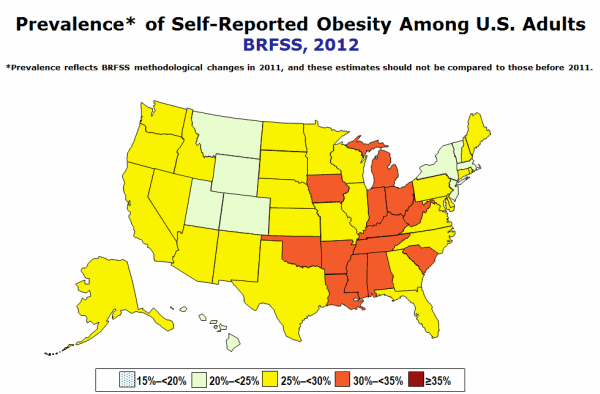
One 20 ounce soda contains 15-18 teaspoons of sugar, responsible for 240 calories. The problem here is that after drinking this amount of liquid, they do not feel as full as having eaten solid food with the same number of calories. Hence there is a tendency to consume even more of this high caloric food! What is the connection between excess consumption of sugary drinks and obesity? In 1970, sugary drinks made up about 4% of US daily caloric intake; by 2001, that had risen to 9%. Children and youth averaged 224 calories per day from sugary beverages between 1999 and 2004, nearly 11% of their daily intake. For children in the age bracket of 6 to 11, calories per day increased by 60%,from 130 to 209 during the time frame of 1989 to 2008. The percentage of children consuming these drinks rose from 79% to 91%. Sugary drinks (including soda, sport drinks and energy drinks) are the top source of teens’ calories in their diet (226 calories per day), beating out pizza!

A study that followed 40,000 men for two decades found that those who averaged one can of sugary beverage per day has a 20% higher risk of having a heart attack or dying from a heart attack than men who rarely consumed sugary drinks. A related study in women found a similar sugary beverage-heart disease link.

(<http://www.hsph.harvard.edu/nutritionsource/sugary-drinks-fact-sheet/> and <http://www.hsph.harvard.edu/wp-content/uploads/sites/30/2012/10/sugary-drinks-and-obesity-fact-sheet-june-2012-the-nutrition-source.pdf>)

The problem with obesity is its relationship to cardiovascular disease (CVD). According to the American Heart Association, obesity is a health risk factor linked to increased cardiovascular condition (CVC), stroke, cancer, hypertension (high blood pressure), diabetes, and early death. The famous Framingham Heart Study (long term investigation) found that obese individuals had an incredible 104% increase in the risk of developing heart failure compared to non-overweight individuals. With more than 35% of US adults being obese, if the trend continues, the obesity rates in adults could reach or exceed 44% in every state by 2030.

A map that shows the incidence of obesity by state follows.



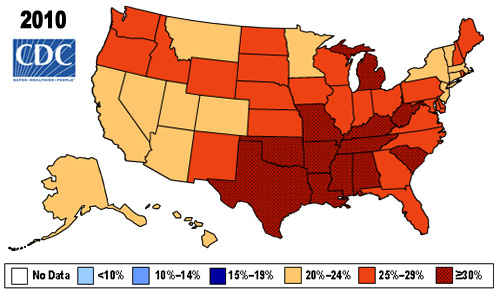
(<http://www.cdc.gov/obesity/data/adult.html>)

**The History of State Obesity Prevalence (from the CDC)**

There was a dramatic increase in obesity in the United States from 1990 through 2010. State prevalence prior to 2011 is provided for historical information only. Historical rates should not be compared to rates from 2011 and forward due to changes in survey methods. No state met the nation's Healthy People 2010 External Web Site Icon goal to lower obesity prevalence to 15%. Rather, in 2010, there were 12 states with an obesity prevalence of 30%. In 2000, no state had an obesity prevalence of 30% or more.

**More on the relationship between sugar, insulin, obesity and Type2 diabetes**

When looking at obesity and sugar consumption, one has to understand the relationship between sugar and insulin. One medical researcher blames insulin for 75% of all obesity. His argument is that insulin, a hormone, directs a source of chemical energy (carbohydrates, protein, and fats) into fat cells. The lowest energy source is protein (amino acids). Consuming protein is less likely to be converted to fat in fat cells because sugar is a preferred source for conversion into fat. The more sugar consumed, the more insulin is released, which in turn converts the sugar into fat for storage. There is a link between people who are overweight (excessive is obese) and their developing Type 2 diabetes. The explanation is that being overweight increases the stress on the body and its ability to maintain proper blood glucose levels (with increased level of sugar in the blood, the pancreas works harder to produce more insulin). Being overweight can cause the body to become resistant to insulin, that is, insulin is no longer able to induce sugar uptake by body cells for cellular metabolism. The map below is an animated one (when viewed online), which shows yearly obesity rates and their changes, from 1985 to 2010. Go to the following website to view the animated map below: <http://www.cdc.gov/obesity/data/adult.html>.



## Connections to Chemistry Concepts (for correlation to course curriculum)

1. **Polarity**—The solubility of citrus oils in BVO is an illustration of the mechanism by which “like dissolves like”: polar and polar, non-polar and non-polar. It is a basic concept that students can easily investigate to arrive at the association between “likes”, assuming they are able to identify the starting substances as polar and non-polar.
2. **Emulsion**—The concept of an emulsion is particularly important in the drinks industry because of the issue of the separation of components in an emulsion. This separation is dependent on the size of the molecules in the emulsion—the smaller the better in terms of limiting the extent of this separation upon long standing (shelf life) of the drink.
3. **Solubility**—What dissolves and what doesn’t in the production of a drink (a solution) requires additives that either have a high solubility or require a solvent that is compatible with the solute—matching polarity characteristics.
4. **Density**—The fact that the citrus oils would normally form a layer in a soda solution is due to both the insolubility of the oil in water as well as a difference in density, the oil being less dense than the water. Adding a more dense liquid (BVO) allows the oil to dissolve in the BVO, producing a mix that “matches” the density of the water and allows mixing (forms an emulsion).
5. **Organic chemistry: saturated, unsaturated bonds**—Adding elements to a molecule, as in the formation of BVO when bromine atoms are added to a carbon compound with double bonds, is possible because of these so-called unsaturated bonds, covalent bonds that can be double or triple between two elements in a molecule. These bonds are considered “reactive”; in a sense they have “extra” electrons for further reaction, even though they are relatively stable “as is”.
6. **Ester**—The formation of the BVO molecule from three fatty acids and an alcohol (glycerol) is an example of an ester reaction. For example. Esters are frequently used in foods for flavoring. Many of the fruit and nut flavors are synthesized through ester reactions.

## Possible Student Misconceptions (to aid teacher in addressing misconceptions)

1. **“Since ‘… there is little evidence and few studies looking at the impact of BVO on casual consumers …’ that obviously means BVOs are safe to drink.”** *While it is true that studies have not yet been done, we should not assume BVOs are inherently safe. That’s why the FDA commissioned studies on BVOs way back in 1970. It is the FDA’s job to test materials we ingest to ensure their safety.*
2. **“Since bromine atoms are heavier than carbon atoms, they MUST be denser than carbon.”** *Actually, that doesn’t HAVE to be true, although bromine IS denser than carbon in this case. There are two factors to consider with density—mass AND volume (M=D/V). Bromine atoms ARE denser than carbon atoms, but not JUST because they’re heavier, or more massive (80 amu for bromine vs. 12 amu for carbon), which would increase the density; they are also just a bit larger (114 pm for bromine vs. 77 pm for carbon), which would decrease the density. Thus, since the mass ratio (bromine:carbon) is significantly larger than the volume ratio, bromine’s density ends up being greater than that of carbon.*
3. **“So, bromine is bleach, eh?”** *This is at least partially, although not entirely, true. According to the article, bromine is “… a reddish-brown nonmetallic element found in seawater that has a* ***bleach-like odor*** *…” That doesn’t necessarily mean that it is bleach, at least not the kind of bleach we usually encounter. The most common bleach used around the house for cleaning and disinfecting is a dilute solution of hypochlorous acid, HOCl. It contains chlorine, which is a member of the* halogens*, the same family as bromine. That means chlorine and bromine have similar properties, one of which is odor. But household bleach contains NO bromine. Having said that, bromine is used in swimming pools as a disinfectant, much like its “cousin” chlorine. In water, bromine forms HOBr, very similar to HOCl; both are bleaches.*

## Anticipating Student Questions (answers to questions students might ask in class)

1. **“What are the main ingredients in sodas?”** *Soda is mostly water that is sweetened with sucrose and high fructose corn syrup. Carbon dioxide is “bubbled” into the liquid for the fizz. Flavorings in lesser amounts give different sodas different tastes. You can make your own soda, including root beer, with healthier amounts of additives, particularly with regard to high fructose corn syrup. Since the root beer is produced by yeast fermentation, it ends up being carbonated! Look at cans of soda for their ingredients, and compare the different types (fruity sodas vs. cola types). Remember that the ingredients are listed from highest quantity to lowest. A generalized listing of ingredients that can be found in soda is as follows:*

*Carbonated Water  
Fructose corn syrup or sucrose  
Caramel color  
Phosphoric acid  
Natural flavors  
Caffeine  
Citric acidSodium citrate  
Sodium benzoate  
Modified food starch  
Ester gum  
Red 40  
Yellow 5  
Malic acid*

A listing of specific contents for some of the name brand sodas is found at <http://www.buzzle.com/articles/soda-ingredients.html>.

1. **“Is it true that Coca Cola contains cocaine?”** Not anymore! *In the early days of Coca Cola (1893), it did contain both cocaine and alcohol! What a combination! Hence the word “coca”. By 1903, anti-narcotic legislation in different states forced Coke’s creator to abandon the cocaine in the drink. However, to this day, Coca Cola does contain some non-cocaine substances extracted from coca leaves as part of the distinct flavor of the drink. For example, in 2003, some 175,000 kilograms of coca leaves were imported by a processing plant in NJ for extracting non-cocaine substances for use in Coca Cola manufacturing. (If you want to read the story behind the creation of the Coca Cola drink after the end of the Civil War, refer to this website:* [*http://www.theatlantic.com/health/archive/2013/01/why-we-took-cocaine-out-of-soda/272694/*](http://www.theatlantic.com/health/archive/2013/01/why-we-took-cocaine-out-of-soda/272694/)*.*
2. **“How is it possible for a diet soda with “diet” (artificial) sweetener not to contain calories?”** *The artificial sweeteners contained in soda are not absorbed in the digestive system and therefore not metabolized. Rather they pass out of digestive system unutilized. If a substance is not metabolized, it is not considered a calorie source.*
3. **“If soda is mostly water, why is drinking soda considered a culprit in the development of obesity in teenagers?”** *The issue is not the water but the sugar in the water. The development of obesity is depended not only on how much soda is drunk but also on how many other sources of calories are consumed (think “chips”!). It is total calories, not just their source. There is controversy over the role of high fructose corn syrup (HFCS) in soda causing obesity. But well-designed investigative studies fail to attribute the obesity problem to HFCS per se. It seems as though total calorie consumption as well as other life style habits (lack of exercise) contribute more to being overweight and obesity than any one particular calorie source such as HFCS.*
4. **“How do Gatorade® and other sport drinks differ from soda?”** *These drinks are developed primarily to replace salts and water lost during vigorous exercise lasting more than an hour. They contain more salt than regular soda. They also contain a mix of sucrose and dextrose rather than HFCS. But, like regular soda, there is citric acid or sodium citrate along with monopotassium phosphate for flavoring. There is no carbonation, of course. The purpose of these sports drinks is to rehydrate (including sugar increases the rate of water absorption compared with water alone) and to restore salts lost in excess sweating. But the simple fact of the matter is that drinking plain water is as effective for rehydration as any of the sport drinks!*
5. **“How is soda carbonated?”** *The soda solution is carbonated in a mechanical rather than a chemical process. The soda solution (with its many ingredients dissolved in water) is passed into a chamber that is devoid of air but filled with carbon dioxide gas at four times atmospheric pressure. The soda solution cascades over a series of metal plates at a temperature of 0 to 4 degrees C. The mechanical action of the flow of soda over the plates at the high pressure mixes carbon dioxide gas into the soda.*

## In-class Activities (lesson ideas, including labs & demonstrations)

1. Have students bring in different containers of soda to check their contents. Include both fruit flavored soda as well as the standard sodas (Coke®, Pepsi®, Dr. Pepper®, ginger ale, orange, citrus, sports drinks). Is any BVO listed? Are calories listed? Are the percent of daily requirements for sugar, salt, fat, and protein listed? Students should then consider just how much of their daily caloric intake is being met by one can of soda. How many cans of soda would produce a person’s maximum recommended daily caloric input? What is considered to be the average number of calories in the diet for a teenager per day? What are other sources of calories besides soda?
2. Distillation of cherry cola or cherry soda allows students to utilize separation techniques and possible identification of components of a soda (by boiling point, odor, and chemical tests).

* One good lab procedure for distillation (with useful questions for the students) is found at <http://www.learner.org/workshops/chemistry/support/act5_b1.pdf>.
* A second lab guide is found at <http://saxonylutheranlovechemistry.wikispaces.com/file/view/Cherry+Soda+Distillation.pdf>.
* And here’s another one, from the Chemical Heritage Foundation, complete with Teacher’s Guide. This one puts the experiment in a historical context, connecting it (loosely) to the discovery of medicines from plant and animal material through the use of separation techniques (<http://wayback.archive-it.org/2118/20100924234202/http://64.251.202.97/EducationalServices/pharm/chemo/activity/sep.htm>)

1. Students can test for the major food groups in soda (use a colorless soda) as well as carbon dioxide. Refer to <http://www.seplessons.org/node/362> for lab procedures. The site includes specific reagents needed for testing the different food groups. Note the activity is not specifically for soda, but for any food material.
2. Students could measure the amount of carbon dioxide gas in their soda drinks. Is it true, for instance, that orange soda has less carbon dioxide than ginger ale or Coke?
3. One lab procedure for measuring the amount of CO2 in soda: “Place an unopened bottle on the scale and tare it. Now shake the bottle vigorously without opening it. You will feel a lot of reactions happening inside. Once the froth has subsided, open the bottle slowly and let the gas or the fizz escape. Make sure that you do not spill out any of the beverage at this point. Now measure the bottle again. Repeat the process a few more times. You will find that after 5-6 readings the mass does not change much. This means, all the fizz has escaped. The difference, you see now, is the total amount of carbon dioxide [that was] present. To confirm your observations, try it with a few more bottles.” Read more at Buzzle: <http://www.buzzle.com/articles/carbon-dioxide-in-soda.html> . This site has additional introductory information. Students can also do the lime water test for carbon dioxide dissolved in water (exhaled air) or colorless soda (Club soda) before and after vigorous shaking.
4. A second approach to this type of experiment is well documented at <http://engineering.oregonstate.edu/momentum/k12/mar06/> and may be more accurate.
5. To measure the volume of carbon dioxide in a carbonated beverage using a syringe, utilize the ChemMatters CD archives (To access this CD archive resource, consult the section titled “Non-web based resources”, further on in this Teacher Guide). The reference for a lab activity measuring carbon dioxide in soda, utilizing a syringe, is found in the “Experimenter’s Notebook”, *ChemMatters* **1984,** *2* (1), p 12.
6. Finally, a very comprehensive lab on carbon dioxide gas and its measurement uses balloons to collect the gas and the volume of collected gas is measured by water displacement. This is a very extensive lab activity with an included collection of thought questions. Access to this activity is found at <http://www.chemheritage.org/Downloads/Classroom-Activities/Teacher-Guide--Priestley.pdf>.
7. Glucose and fructose, both found in soda are metabolized differently. Glucose can be taken up by cells directly and used in respiration (for generating energy. Fructose cannot be utilized directly by cells for energy. Rather, it is processed by the liver and is converted into several lipid-related molecules. In making high fructose corn syrup (HFCS), some of the glucose found in corn syrup is enzymatically converted to fructose to increase the sweetness of the corn syrup. A lab exercise on the conversion of glucose to fructose, utilizing enzymes, is found at <http://www.math.unl.edu/~jump/Center1/Labs/ConversionofGlucosetoFructose.pdf>.

The reference also contains useful background information.

1. A lab activity to illustrate polar/non-polar properties is easily done with procedures outlined in most high school textbooks and lab manuals. One example of a microscale lab investigating polar and non-polar substances is found at <http://dwb.unl.edu/chemistry/microscale/MScale26.html>. This activity allows students to make the connection between what dissolves in what, that “like dissolves like”. Utilizing water vs. vegetable oil for starters, students then try dissolving common solids (sugar, salt, solid iodine and naphthalene) as well as some liquids (isopropyl alcohol, an intermediate on the polar/non-polar scale, toluene, hexane, vinegar, kerosene and lamp oil).
2. Students can perform electrolysis of a bromide salt (CuBr2) in solution to produce liquid bromine, Br2, which will be apparent by its color and separation from the water solution. This is the process that Herbert Dow used in the late 19th C. to extract bromine from underground brine, rather than a complex series of chemical reactions that had been used previously. Refer to the following lab procedure: <http://www.flinnsci.com/media/620463/91208.pdf>.

Note that CuBr2 is used in this experiment to make the Br2, and KI is also used to prepare I2.

1. Students can compare the density of regularly sweetened soda with diet soda. Students can place a can of diet soda and a can of regular soda in a large container of water (bucket) and see which, if any, sinks and which floats. The diet soda will not sink. Have students read the contents of each type of soda and note the differences. What component might be most responsible for the higher density of regular soda? Students could also determine the density of each type of soda using standard methods for determining density of a liquid. (Use very cold soda and pour the liquid slowly into a graduated cylinder to minimize evolution of CO2.) Ask the students if the foaming of the soda makes a difference in measuring the mass and volume of the soda. Students could also compare different sodas (Coke® vs. Pepsi® vs. Mountain Dew®, etc.).

## Out-of-class Activities and Projects (student research, class projects)

1. The whole controversy surrounding the health effects of high fructose corn syrup (HFCS) presents a challenging research project for some students. What is the research data that suggests eating HFCS is a problem—how much consumption is necessary for it to be a problem? How does fructose metabolism differ from glucose metabolism? Does this create detrimental health problems for people? What is the evidence?
2. The role of soda consumption by youth in the obesity epidemic could be researched by students and presented to the class. What are some of the suggested changes in lifestyle for children and teenagers that are doable and practical? Students should survey their schools for soda and sweet drinks vending machines. Should the machines be part of school? Are they there just for making money for school? Can they be removed, after consulting the student body, explaining the problem of having a convenient and tempting source of sugary drinks?
3. Students could make their own soda concoctions, skipping the high sugar commercial drinks. A simple, basic recipe is found at <http://www.sheknows.com/food-and-recipes/articles/808584/how-to-make-homemade-soda>.

## References (non-Web-based information sources)

**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013, and all available Teacher’s Guides, beginning February 1990). 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)**. Scroll to the bottom of the page and click on the *ChemMatters* DVD image at the right of the screen to order or to get more information.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online on the same Web site, above, as well as selected articles from other past issues (2002 forward). Simply access the link above and click on the “Past Issues” button directly below the “M” in the *ChemMatters* logo at the top of the Web page. If the article is available online, you will find it there.**



**30 Years of *ChemMatters***

Available Now!

Davenport, D. Joseph Priestley and the American Lunch. *ChemMatters* **1983,** *1* (1), pp 14–15. This article is entertaining as well as informative. It provides some important history about the work of Joseph Priestley, a British pastor as well as an experimental chemist who eventually settled here in the USA (in north central Pennsylvania). The fun part of the article is an explanation of the origin of the word “sandwich”. But Priestley was an important figure in experimental chemistry which included his development of carbonated water.

Poscover, G. What’s That Fizz? *ChemMatters* **1984**, *2* (1), pp 4–5. The author explains the commercial process for the carbonation of soda. This is a mechanical process in contrast to the carbonation of alcohol-based products such as beer and champagne which is produced by yeast through the fermentation process by which sugars are converted to alcohol and carbon dioxide. The article also delves into the behavior of gases in solution and provides explanations based on the gas laws.

Graham, T. Sports Drinks: Don’t Sweat The Small Stuff. *ChemMatters* **1999,** *17* (1), pp 11–13. This article spells out the benefits of sports drinks as well as explaining when water would be as useful as a sports drink! Included is a chart of some of the more common beverages, listing the amount of calories, sodium, potassium and carbohydrates they contain, compared with several sports drinks that are also listed.

Haines, G. Corn—The A”maiz”ing Grain. *ChemMatters* **2006.** *24* (4), pp 4–7. The author writes about all aspects of corn, including the controversial subject of genetically modified corn (GMC). She lists some of the benefits of genetically modifying the plant such as incorporating a gene that produces a toxin that protects the plant from insects, eliminating the need to spray insecticides, with obvious benefits. Corn is also the source of ethanol, a gasoline replacement or additive fuel. Finally it is the source of high fructose corn syrup so widely used in the food industry.

Rohrig, B. Serendipitous Chemistry. *ChemMatters* **2007,** *25* (3), pp 4–6. This article about some serendipitous chemical discoveries includes a discussion about several of the artificial sweeteners (their molecular structures are illustrated), including how some of these chemicals were originally labeled health hazards.

Rohrig, B. Are Energy Drinks Good For You? *ChemMatters* **2008**, *26* (4), pp 10–11. In this article, the author lays out the arguments for and against energy drinks in terms of health considerations. There is also a very useful one-page illustration of a can of energy drink listing the major contents in the drink and their functions.

Brownlee, C. Sweet but Good for You? *ChemMatters* **2011,** *29* (2), pp 12–14. The author explains how high fructose corn syrup (HFCS) is produced from corn starch and why it is sweeter than the plant sugar, sucrose. There are illustrations of the important sugar molecules (mono-, di- and polysaccharides) involved in the production of HFCS.

Haines, G. Sugar in the Blood Boosts Energy. *ChemMatters* **2011,** *29* (3), pp 6–7. This short article explains the biochemistry behind converting the chemical potential energy in glucose to usable energy for our bodies through chemical transformations involving cellular ATP conversions.

Brownlee, C. The Skinny on Sweeteners—How Do They Work? *ChemMatters* **2011**, *29* (3), pp 15–16. The author explains the differences in molecular composition for several of the most common artificial sweeteners, how each of their sweetness sensations compare with each other and with sucrose (table sugar), glucose, and fructose. Their safety is also discussed.

## Web Sites for Additional Information (Web-based information sources)

**More sites on bromine**

The origins of the bromine industry in the USA, which became a serious competitor to the European chemical industry in the 19th C. is a very interesting chemistry story. In particular was the utilization of electrolysis for extracting bromine from underground brine by Herbert H. Dow rather than an involved, multistep chemical process to free the bromine from the brine as was being done in Europe. This was the beginning of the Dow Chemical industry. Refer to the story at <http://www.acs.org/content/acs/en/education/whatischemistry/landmarks/bromineproduction.html>.

Concise information about bromine and bromides, their use, and their impact on health is found at [www.portal.state.pa.us/portal/server.pt/document/1098747/fact\_sheet\_-\_bromide\_with\_point\_references\_](http://www.portal.state.pa.us/portal/server.pt/document/1098747/fact_sheet_-_bromide_with_point_references_).

**More sites on** **fructose as the source of obesity**

In the reference, <http://earthsky.org/human-world/a-brief-history-of-high-fructose-corn-syrup> , a useful argument is made about the limitations in studies done linking fructose in sugary drinks to obesity when diets high in fructose are included along with high caloric intake from other sources (hypercaloric). When diets used only fructose (no other sugars included which is known as isocaloric), there was no weight gain. Singling out one dietary hazard to the exclusion of others has the potential to create a lot of confusion and polarized opinions. Compare this article with research done on rats at <http://www.sciencedaily.com/releases/2010/03/100322121115.htm>, and the corn syrup industry’s position on the subject at <http://www.corn.org/products/sweeteners/high-fructose-corn-syrup/>.

**More sites on** **making your own soda**

For students who want more recipes for making their own soda and fruit drinks, refer to the following websites: <http://www.ehow.com/video_12293197_make-own-fruit-sodas.html> and <http://www.ehow.com/how_6554049_make-soda-pop-scratch-home.html>.

**More sites on health effects of soda**

A balanced discussion about the various potential health effects from drinking soda is found at <http://www.wisegeek.org/what-are-the-health-effects-of-drinking-soda.htm#didyouknowout> . This might be a useful article for students to read, particularly if they are assigned to research this topic for a class presentation.

A complementary research article (abstract) on the difficulties of assigning blame to soda drinking for causing overweight is found at <http://www.ncbi.nlm.nih.gov/pubmed/19087367> . This might be useful to students in understanding the difficulties in obtaining reliable studies on human subjects. The number of variables is hard to control.

Several articles that discuss the extent to which sodas and other sweetened drinks are healthy are found at <http://www.webmd.com/diet/features/can-soft-drinks-be-healthy> and

<http://www.webmd.com/diet/features/sodas-and-your-health-risks-debated>. This latter reference includes a discussion about studies done to evaluate the degree to which soda and similar drinks contribute to health concerns such as cardiovascular disease.

**More sites on the history of the soda industry**

An interesting catalog of events related to the development of soda fountains earlier in the 20th century may be of interest to students (and teachers?!) who probably have never experienced such places. This site includes the history behind the creation of soda, beginning with Joseph Priestley discovering a technique for producing carbonated water. Refer to <http://en.wikipedia.org/wiki/Soft_drink>.

# Shampoo: From Lab to Shower

## Background Information (teacher information)

**More on** **the history of shampoo**

Before the advent of shampoos, people mostly used some kind of soap which of course could be irritable to both skin and eyes, depending on the type of soap. If you are familiar with something like naphtha soap, you know how irritable that soap can be! The second issue with using soap is that it does not produce much lather in hard water. Using soap, even today, usually leaves the hair looking dull since soap is alkaline. One of the earliest attempts at developing a better product for washing the hair was done by a Berlin chemist, Hans Schwarzkopf in 1908. His product was Schwarzkopf’s attempt to get beyond the expensive oils and harsh soaps used to wash hair. His concoction was a water-soluble powder shampoo which became very popular in all the drugstores of Berlin. Given that the powder shampoo was convenient to use, it still left the hair dull because of alkaline reactions. But this same business eventually developed the first non-alkaline shampoo in 1933.

In May 1908, the *New York Times* published a series of steps for shampooing the hair. (Refer to "[How to Shampoo the Hair](http://query.nytimes.com/gst/abstract.html?res=9904E5DA143EE233A25753C1A9639C946997D6CF)" at <http://query.nytimes.com/gst/abstract.html?res=9904E5DA143EE233A25753C1A9639C946997D6CF>. The New York Times. Archives. May 10, 1908—only available to subscribers, perhaps your school library?). It is too long to reproduce in its entirety, but the essence of the process of washing the hair included the use of an oil-based Castile soap, applied with a stiff brush. That was followed by rinsing the hair several times. Although the regimen that was spelled out was time consuming, the general recommendation was that people should shampoo the hair as “*often”* as every two weeks! But they could also wait from a month to six weeks if their hair was in good condition.

The first synthetic detergent shampoo was introduced in the early 1930s but it did not have the good properties of the synthetic shampoos we have today which appeared on the market in the 1960s.

**More on** **the essentials of shampoo**

Shampoos are a complex mix of chemicals to perform a variety of tasks when in contact with our hair. The following information about the essentials of shampoo, ending with conditioners, is taken directly from the website, <http://sci-toys.com/ingredients/shampoo.html>.

The purpose of a shampoo is to clean the hair! The shampoo must not clean too well, or all of the protective oils in the hair would be stripped out. It must not make the hair smell bad, despite the bad smells of the detergents it is made of.

To sell well, the shampoo must look good, must feel thick or creamy in the hands, and must produce a nice feeling lather. It must smell nice, and not be too expensive.

Other selling points might be the herbal extracts currently in fashion, or amino acids from exotic protein sources like silk or the milk of pigmy goats.

##### Detergents

The most common ingredient in shampoos is also the most common [detergent](http://sci-toys.com/ingredients/detergents.html) in use in other products, a class of surfactants known as *straight-chain alkyl benzene sulfonates*. An example is [Ammonium Lauryl Sulfate](http://sci-toys.com/ingredients/ammonium_lauryl_sulfate.html), or its sodium relative, or the slightly larger related molecule *ammonium lauryl ether sulfate*, sometimes abbreviated as *ammonium laureth sulfate*.

These detergents work best in water that has little calcium and magnesium, as these elements bind to the detergent and make an insoluble scum. So [tetrasodium EDTA](http://sci-toys.com/ingredients/edta.html) (ethylene diamine tetraacetate) is used to sequester the calcium and magnesium from the detergent, while keeping them soluble so they rinse away without scum.

[Cocamide DEA](http://sci-toys.com/ingredients/cocamide_dea.html) (or MEA or TEA) is used as a foaming agent, to make the lather. The other surfactants will generate a certain amount of suds, but this foaming agent is added to get the amount just right. Besides its foam stabilizing effects, this agent is also a viscosity booster (it's thick).

Another foam stabilizing detergent is [PEG-5 cocamide](http://sci-toys.com/ingredients/polyethylene_glycol.html), which is a foam stabilizer, surfactant, and emulsifier.

The detergent [cocamidopropyl betaine](http://sci-toys.com/ingredients/cocamidopropyl_betaine.html) is added for several of its special properties. It is milder on the skin than the benzine sulfonates, so adding it to the mix reduces the amount of the harsher detergents needed. It is thicker than the other ingredients, so it can be added to make the mix have the right viscosity. It has anti-static properties, so the hair doesn't generate an electric charge and jump to the plastic combs and brushes used when drying the hair. It is a humectant, attracting moisture from the air, thus keeping hair from drying out. Lastly, it has antibiotic properties that can prevent spoiling of the shampoo.

The surfactant [ammonium xylenesulfonate](http://sci-toys.com/ingredients/xylenesulfonate.html) is a *hydrotrope*, a compound that makes it easier for water to dissolve other molecules. It is added as a thickener, and to help keep some of the odd ingredients added for marketing effect in solution, including perfumes. [Glycerol stearate](http://sci-toys.com/ingredients/glycerol_monostearate.html) is another emulsifier used for this purpose.

##### Special effects

The wax [glycol distearate](http://sci-toys.com/ingredients/wax.html) is added to make shampoos opaque and pearlescent. It has tiny flakes that mix well with surfactants, and stay in solution. They also add shear-thinning qualities, making liquid hand soaps pump out of the bottle easier.

Sodium chloride (table salt) is used to thicken the mixture if the main surfactants are sodium lauryl sulfates. If the surfactants are ammonium based, then ammonium chloride is used. Salt can make the shampoo harsh and sting the eyes, so more expensive thickeners are used to keep the salt levels low.

Modified [cellulose](http://sci-toys.com/ingredients/methylcellulose.html) based thickeners are often used, along with the surfactant based thickeners already mentioned.

[Glycerin](http://sci-toys.com/ingredients/glycerine.html) is added as a humectant (draws moisture from the air), as is [propylene glycol](http://sci-toys.com/ingredients/glycols.html), which is also a preservative.

There are many additives put in shampoos and conditioners that appear to be there mainly for marketing purposes. Honey, various herb extracts, and similar items might add to the fragrance, but are unlikely to have any effect in the concentrations used. Amino acids can act as conditioners, but the source of the amino acid is not important. Silk amino acids are no different from soy amino acids, except in the proportions of which particular amino acids are contained.

##### Preservatives

Two widely used preservatives, [DMDM hydantoin](http://sci-toys.com/ingredients/DMDM_hydantoin.html) and [imidazolidinyl urea](http://sci-toys.com/ingredients/imidazolidinyl_urea.html) are found in many shampoos, to prevent fungal and bacterial spoilage. They release formaldehyde to kill germs.

Another broad-spectrum biocide is [isothiazolinone](http://sci-toys.com/ingredients/isothiazolinone.html) and the related [methylisothiazolinone](http://sci-toys.com/ingredients/isothiazolinone.html) and [methylchloroisothiazolinone](http://sci-toys.com/ingredients/isothiazolinone.html).

[Sodium benzoate](http://sci-toys.com/ingredients/sodium_benzoate.html) is another preservative used in shampoos. It kills bacteria, fungi, and yeasts, and works well in acidic mixtures.

Another bactericide used is [2-bromo-2-nitropropane-1,3-diol](http://sci-toys.com/ingredients/2_bromo_2_nitropropane_1,3_diol.html).

##### pH balance

The surface of a strand of hair is covered with overlapping sheets, somewhat like the scales on a fish, or the shingles on a house. This surface is called the *cuticle*.

Alkaline solutions raise these scales, so they stand up. This makes the hair rougher, makes it look dull, and makes the hair shafts stick together due to the rough texture.

Most shampoos are made slightly acidic, to keep the cuticle smooth and lying flat on the hair shaft. Ingredients like [citric acid](http://sci-toys.com/ingredients/citric_acid.html) are added to acidify the shampoo.

As the shampoo mixes with the water in the shower or bath, or mixes with dirt on the hair, it can become less acidic as the acids mix with alkaline water or dirt. A compound that releases more acidifying ions when the acidity gets low, or absorbs acid when the acidity gets too high, is called a *buffer*.

A typical buffering agent used in shampoo is [sodium citrate](http://sci-toys.com/ingredients/sodium_citrate.html). Since the goal is to keep the shampoo slightly acid, the term "pH balanced" is actually a misnomer. We want the balance to be tipped slightly to the acidic side.

##### Conditioners

Conditioners are compounds added to keep the hair cuticle smooth and slippery.

Silicone oils such as [dimethicone](http://sci-toys.com/ingredients/dimethicone.html) and [cyclomethicone](http://sci-toys.com/ingredients/dimethicone.html) are used to make the hair shiny and slippery.

Humectants (moisturizers) like [panthenol](http://sci-toys.com/ingredients/panthenol.html) help keep the cuticle moist, so that the scales do not stand up.

Long chain fatty alcohols like [cetyl alcohol](http://sci-toys.com/ingredients/cetyl_alcohol.html), [oleyl alcohol](http://sci-toys.com/ingredients/oleyl_alcohol.html) and [stearyl alcohol](http://sci-toys.com/ingredients/stearyl_alcohol.html) lubricate the hair. One end of the molecule binds to the hair, leaving the slippery fatty end on the outside to rub against other strands of hair, or a comb.

Quaternary ammonium compounds are cationic surfactants that bind well to anionic surfaces like the protein in hair. The ammonium end sticks to the hair, leaving the long fatty end of the molecule to act as a lubricant. They are slightly conductive, so the reduce the buildup of static electricity.

The "quats", as they are called, include compounds like *stearalkonium chloride*, *disteardimonium chloride*, *quaternium-5* or *quaternium-18*, *polyquaternium-10* and they are all similar in form and function to [cetrimonium chloride](http://sci-toys.com/ingredients/cetrimonium_chloride.html).

These compounds are also widely used as fabric softeners, for all of the same reasons they make good hair conditioners. They are also used to thicken the shampoo.

The emollient *isopropyl palmitate* is used as a skin softener, moisturizer, and as an anti-static agent.

(<http://sci-toys.com/ingredients/shampoo.html>)

**More on** **the safety of some chemical ingredients in shampoo**

Some opinions about the safety of three common ingredients in shampoo—sodium lauryl sulfate (SLS) sodium laureth sulfate (SLES), and dimethicone—are not rooted in scientific testing. Again, the government has allowed the use of these three chemicals in shampoo after not finding any issues with them when tested on animals other than humans. The protocol for testing the efficacy of these chemicals is nicely documented in a short summary at the following government website: <http://www.ncbi.nlm.nih.gov/pubmed/14555417>. One of the issues concerns whether or not these chemicals are absorbed through the skin.

An interesting reaction from one writer (connected to the beauty products business) about the safety of silicone containing products (i.e., when absorbed through the skin) blames certain groups for misrepresenting the research facts. In his responses to people who are suggesting that some cosmetic and hair product ingredients are unsafe, he uses a good amount of chemistry to defend the beauty product chemicals. Part of his defense, based on chemistry and government testing, includes the following:

FACT: Cosmetic grade silicones have a molecule size that is too large to enter or clog a human pore. Silicone fluids are considered “breathable” because these large molecules have wide spaces between them, which allow other ingredients and air to penetrate. The most basic silicone in cosmetics is Dimethicone. It is a clear, non-reactive, liquid product that can range in thickness, depending on the length of its polymer backbone, from watery thin to taffy thick. Cyclomethicone is a shorter cyclic molecule which has many of the same properties of dimethicone except that it evaporates while dimethicone does not. Dimethicone copolyol is a silicone which contains an -OH group which makes it more soluble in water. This makes it easier to incorporate into water-based formulations but also reduces the usefulness of the silicone.

… Hospitals and other medical practices primarily use SILICONE based medical adhesives because silicone has an extremely low occurrence of allergenic skin reaction…as opposed to latex based medical adhesives, which used to be the standard (we know how prevalent latex allergies are). …Medical practitioners concur that silicone based medical adhesives are safe to use in close proximity to OPEN WOUNDS. What better proof of the safety of cosmetic grade silicone could you ask for?

(<http://kjbennett.com/cosmetic-silicone-safety-fact-fiction/>)

In hair care products, dimethicone is used to provide smoothness, particularly in conditioners and detanglers, where the ingredient helps smooth hair and provide better comb-through. Because dimethicone leaves a sort of covering on the hair strands, it can also make hair appear shinier.

Is dimethicone safe? The FDA approved dimethicone for personal care products, and it is generally considered to be safe to use. The Cosmetic Ingredient Review (CIR) also evaluated the scientific data and concluded that it was safe for use in cosmetics. (<http://www.annmariegianni.com/ingredient-watch-list-dimethicone-the-smoothing-silicone-that-exacerbates-acne/>)

Another example of how misinformation can lend itself to unscientific statements about a product or chemical, in this case, SLS, can be found in an article at <http://science.howstuffworks.com/environmental/green-science/sodium-lauryl-sulfate1.htm>. This article contains some of the questions or concerns about SLS. The idea that SLS causes cancer was initiated by an unfounded email rumor in 1989. The evidence is not there to support such a rumor. What it may cause (when using shampoo) is skin irritation in some individuals who are sensitive to it, if it is left on the scalp too long. And, as is often the case, some people make the argument that if SLS is found in garage floor cleaners, it must be harmful! SLS is not listed as a carcinogen by important research groups including the International Agency for Research on Cancer and the American Cancer Society, among others. As for the toxicity of SLS, you would have to swallow about 16 pounds of the chemical before it would have serious health consequences. It is also found in toothpaste. On the tube is the warning not to swallow the toothpaste for one reason only—it may give a person diarrhea, not cancer!

Information about sodium laureth sulfate from the government is a readable summary at <http://www.ncbi.nlm.nih.gov/pubmed/20634505>.

A suggestion is made by one medical doctor that shampoo should contain 18-MEA (18-methyleicosanoic acid), a natural substance in hair and is used to restore that chemical if lost because of the use of a variety of compounds in shampoo.

Environmental factors and chemical treatment as well as everyday grooming processes can have an adverse effect on the integrity of 18-MEA. Although 18-MEA and the other hair surface lipids appear to be resistant to extraction with organic solvents, they can be removed readily by alkaline hydrolysis. This suggests that the use of high pH products, such as perms, hair dyes or hair relaxers, could deplete these important lipids from the hair surface. Studies on wool fibers have shown that exposure to natural, or artificial, weathering or UV irradiation increases the hydrophilicity and wettability of fibers. Additionally, exposure to UV irradiation has also been shown to deplete wool of its lipid content. Of the fatty acids, 18-MEA appears to be lost to the greatest extent; therefore, it is necessary to restore18-MEA to maintain healthy hair.

(See more at: <http://www.cosmeticsandtoiletries.com/formulating/function/repair/231621741.html#sthash.7judEkMB.dpuf>.)

There is an interesting set of charts listing the ingredients in shampoos for different types of hair. The list also shows the function of each substance. It is quite extensive and too long a series of columns to include here. It is best viewed at this website: <http://www.nisim.com/NewHair-FAST-Shampoo-Kalo-Kerte-Ingredients-s/45.htm>.

**More on** **making your own shampoo- primary ingredients (and their use)**

For some, making one’s own shampoo is considered an important activity in order to ensure the use of ingredients that perform the task of cleaning the hair without damaging it or risking the use of what some people perceive, rightly or wrongly, as health-impairing chemicals. In looking at these various recipes, one can see what appears to be common and essential ingredients to both wash the hair and restore its sheen.

This raises the question, then, as to how necessary are all the other ingredients found in commercial shampoos? After reading this list of recipes for making shampoo, go back to the introductory section on the long list of ingredients found in commercial shampoos for comparison. What are the essential elements in a homemade shampoo? What compounds in the commercial shampoo serve the same function?

One example of some basic shampoo recipes includes the following ingredients:

For normal hair, or as a base to add your own scents, use

* 1/4 cup distilled water
* 1/4 cup liquid Castile Soap—use unscented, but you can choose your favorite
* 1/2 teaspoon jojoba, grape seed, or other light vegetable oil
* Flip Cap Bottles or Foaming Bottles to dispense

For dry hair, a suggested combination of ingredients is:

* 1/4 cup distilled water
* 1/4 cup liquid Castile Soap - your favorite scent
* 1/4 cup aloe vera gel
* 1 teaspoon glycerin
* 1/4 teaspoon avocado oil or jojoba oil
* Flip Cap Bottles or Foaming Bottles to dispense

For stimulating the scalp in the washing process, the following combination of ingredients is suggested:

Combine

* 1/4 cup distilled water
* 1/4 cup liquid Castile Soap - I use unscented, but you can choose your favorite
* 2 tsp jojoba oil
* 1/8 tsp peppermint essential oil
* 1/8 tsp tea tree essential oil
* Flip Cap Bottles or Foaming Bottles to dispense

Mix all ingredients, then add 1/4 cup distilled water.

(Source for the above three recipes is found at <http://www.instructables.com/id/Homemade-Shampoo/>)

From another source is a different approach with natural materials and an explanation of what the course of treatments and chemicals do to the hair when utilized.

Knead a few tablespoons of olive oil into your dry scalp and hair. Swathe your oiled-up curls with a shower cap and take a thirty minute breather...snooze, toss back a latté, whatever. Then just shampoo as usual to reveal a refurbished mane…

Every night, rub your scalp and massage your mane with a solution of 50/50 distilled white vinegar and water. This homemade "hair-product-residue remover" leaves behind the glistening, polished locks you've always dreamed of.

And for the simplest of shampoo replacements, combine one tablespoon of baking soda with two tablespoons of water -- remembering that this isn't going to look or feel like any shampoo you're accustomed to. Think of it more like a shamp-paste. There won't be mountains of foamy bubbles (you get those in commercial products because of the chemicals added to get all that lather). Work the paste through your hair and rinse thoroughly, for unexpectedly clean and remarkably shiny hair.”

(<http://www.goodhousekeeping.com/beauty/natural-shampoo-recipe-460409>)

Finally, for people who have some concerns about commercial shampoo preparations (and maybe want to save money), the following formulation for a very basic “do-it-yourself shampoo” is as follows:

* **1 Tbsp. baking soda**
* **1 cup water**

Place the mixture into a squirt bottle so that when it is to be used, it can first be shaken, then squirted directly onto the scalp and hair. After massaging into the scalp and hair, it is rinsed off. (source: <http://www.diynatural.com/homemade-shampoo/>)

This is followed by a homemade conditioning rinse in order to restore the pH of the hair and to smooth the hair cuticle. This conditioner will also keep the hair from feeling greasy. The conditioner is made as follows:

* **1 Tbsp. apple cider vinegar**
* **1 cup water**

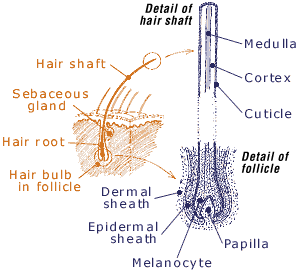
Mix the two ingredients into a squirt bottle which is always shaken before squirting onto the scalp and hair. Massage into the scalp and hair for a minute or two, then rinse thoroughly. (source: <http://www.diynatural.com/homemade-conditioner/>)

When you look at the two most important ingredients in this basic shampoo, your will see that the baking soda with water will produce an alkaline solution like soap, which is good for dissolving oily substances. The addition of the vinegar-based solution, an acidic conditioner, will neutralize the baking soda and wash it away. Conditioners are supposed to be acidic to change the pH of the hair back from alkaline to a pH range of 2.0.

**More on the chemistry behind hair structure and its behavior with shampoo**

The behavior of hair when certain chemical mixtures, including shampoo, are applied, involves some chemistry, in particular the changing of chemical bonds within and between hair follicles. The basics of hair structure are as follows:

* The hair follicle, located in the fatty region of the scalp
* A bulb, inside the follicle, which produces new hair cells
* A shaft (what we see as hair) is formed by the new hair cells pushing out older (and dead) cells

The shaft has a complex structure consisting of an outer layer, the cuticle, which is composed of dead epithelial cells that overlap each other like shingles on a roof. Inside the cuticle is the cortex which contains the protein that gives hair its strength and determines it shape. The cuticle also contains pigment which gives the hair its color. The particular category of protein in the cortex is called keratin. As the shaft grows out of the scalp, the keratin hardens as chemical bonds cross-link one part of a protein molecule to another.

(drawing at right from <http://www.exploratorium.edu/exploring/hair/hair_2.html> )

Hardening of the keratin is done through three types of bonds—ionic, covalent, and the weakest, hydrogen. Referring to a typical protein molecule, made from a long chain of amino acids, parts of the protein have ends with ionized carboxyl (–COOH) and amino (–NH2) groups. The –COOH group loses a hydrogen ion, H+, to become –COO- and the –NH2 group gains an H+, forming the charged end, –NH3+. An ionic bond can then form between the positive and negative ends, which is the basis for linking two protein molecules in the hair. This linkage or bonding is known as a salt bridge when single ions join organic molecules.

A second type of cross-linked bond that forms between protein molecules is a disulfide bond, which involves two sulfur-containing amino acids called cysteine. The keratin in human hair is considered to be about 14% cysteine. In this molecule, there is an –SH group projecting from each molecule. If the –SH groups lose their H’s (through oxidation), a covalent bond can form between the two sulfurs, linking the two protein molecules. This bonding causes the polypeptide chains of two proteins to bend into loops. Solutions called relaxers straighten curly hair by breaking disulfide bonds. In turn new disulfide bonds are formed involving different cysteine molecules which means the curls are lost. A different kind of solution allows curls to form by first breaking the disulfide bonds, putting the hair in curlers, then treating the hair with another solution (called a “neutralizer”) that then allows the reforming of different disulfide bonds that hold the curls. So the hair shape, macroscopically, is produced by the microscopic changes at the protein level.

Finally, weak hydrogen bonds can form between hydrogen atoms and other elements such as nitrogen and oxygen within two protein molecules. The vibratory nature of hydrogen, nitrogen, and oxygen atoms can produce temporary dipoles (+ for hydrogen, – for nitrogen and oxygen) allowing for weak electrical attractions. Although hydrogen bonds are weak, there is strength in numbers if you consider that there will be millions of these bonds within the hair. But these weak hydrogen bonds can be broken with water, a polar molecule. When water penetrates the hair shaft, its polar nature interacts electrically with the negatively charged nitrogen that has formed a hydrogen bond, weakening the electrical attraction and breaking the hydrogen bond. With the breaking of hydrogen bonds, the hair mass swells, making it easier for other chemicals to penetrate the shaft.

Ionic bonds between the hair’s protein molecules are broken when using alkaline or acidic solutions. The –OH– of a basic solution is attracted to and reacts with the –NH3+ group that is involved with an ionic bond. The reaction is as follows:

–NH3 + + –OH– 🡪 –NH2 + H2O

The interaction of the positive and negative charges causes the ionic bond between the –NH3+ and the –COO– to collapse.

In strongly acidic solutions (pH 1.0 to 2.0), both hydrogen bonds and salt bridges are broken. The disulfide bonds in the hair’s protein chains remain intact. Increasing the pH to 8.5 causes some disulfide bonds to break, causing the cuticle to become ruffled, which in turn gives the hair a roughness, making the hair look dull. At pH 12, all three types of bonds are broken, and the hair dissolves! This fact is the basis behind commercial solutions for removing hair (depilation).

Hair is normally acidic, in the range of 4.0 to 5.0. Because shampooing tends to leave hair alkaline, the hair can be restored to the acidic range with acidic rinses, including such natural things as lemon juice and vinegar.

As mentioned in the *ChemMatters* article, a group of chemicals called surfactants are present in shampoos to “accelerate” the water absorption process by the hair as well as putting oils into solution for rinsing away due to the hydrophilic and hydrophobic ends of the surfactant.

The first commonly used surfactant was soap. Indeed, the first shampoos were just solutions of soap prepared from water, soap and soda (sodium carbonate) by British hairdressers during the heyday of the Empire on which the sun never set. They coined the word shampoo from "champo," a Hindi word meaning to massage or knead.

(<http://www.washingtonpost.com/wp-srv/national/horizon/dec98/shampoo.htm>)

The increased water absorption by the hair is due to the chemical fact that the surfactant molecules act like soap, reducing the surface tension of water so the water molecules don’t tightly “clump” together. The surfactant molecules wedge between the water molecules, reducing the surface tension and allowing water to spread out over a particular surface such as hair. An interesting aside concerning water and surface tension is the fact that the surface of our lungs (the microscopic alveoli surfaces) is coated with not only water but also a detergent molecule (surfactant) without which we would not be able to inflate our lungs upon inhaling. Because of the high surface tension if there was only the water, the alveoli chambers would collapse, preventing them from filling with air. (The detergent’s chemical composition is not fully detailed, but it is thought to be about 90% phospholipids and 10% protein).

**More on conditioners**

Because hair is subjected to a variety of forces and events that affect the appearance of the hair (e.g., looking dull and dry), it must be conditioned periodically, usually when the hair is washed. Conditioners replenish the natural oils that lubricate the hair as well as rehydrate it. One interesting aspect of conditioners, chemically speaking, is that they contain cations which are attracted to the anions present in hair. This keeps the conditioners in the hair after multiple washings. The conditioners also give the hair weight and shine as well as preventing what is called “frizzing” (forming the hairs into small, tight curls).

Some of the ingredients in conditioners and what they do is as follows:

* Stearalkonium chloride—repairs split ends
* Phenyl trimethicone—lubricates the hair
* Polyacrylamide—acts as a holding agent to keep the hair in a desired shape (like a diluted hair gel agent)
* Cyclopentasiloxane—is a solvent
* Moisturizers—contain a high proportion of humectants which are hygroscopic substances, attracting and holding water because of hydrophilic groups (usually hydroxyl groups) in the molecules
* Sunscreen—protects against color loss and protein degradation
* Sequestrants—essentially various types of chemicals that make hard water soft by chemically tying up metal ions such as magnesium and calcium. One of the more common chemicals is EDTA (ethylene diamine tetraacetic acid), a chelating agent of metal ions
* Fatty alcohols for moisturizing—included are lauryl alcohol, cetyl alcohol, myristyl alcohol, stearyl alcohol, cetearyl alcohol and behenyl alcohol

Conditioners, which are acidic, protonate the amino acids in the conditioner, giving the substance a positive charge, allowing for more hydrogen bonds among the keratin scales which gives the hair shaft a more compact structure.

And here is a final statement on hair:

*”Babies haven't any hair;  
Old men's heads are just as bare;  
Between the cradle and the grave  
Lies a haircut and a shave.”*

~ Samuel Hoffenstein (1890–1947)  
*Songs of Faith in the Year after Next*

## Connections to Chemistry Concepts (for correlation to course curriculum)

1. **Polarity**—The shampoo article presents an opportunity to demonstrate the concept of polarity through various combinations of polar and non-polar substances, the addition of a soap or detergent to change the behavior of non-polar molecules in water.
2. **Solubility**—Students can be reminded of the various factors that affect solubility and which of them is important when shampoo is added to water.
3. **Surface tension**—Because water is a polar molecule, it has high surface tension which must be broken if the water is to get into the hair to dissolve away the oils when shampooing. The use of soap-like molecules (surfactants) that have both polar and non-polar ends “mate” with the non-polar oils and the polar water molecules to produce an emulsion of the two classes of chemicals.
4. **Micelle**—When dispersed in water, soaps and detergents form the clusters called micelles. Micelles are very important in the biological world. For example, bile salts emulsify the products of digestion of fats by combining with them to form micelles.
5. **pH scale**—The cleansing action of shampoo depends on the pH of the mixture, usually in range of 5.5 to 7. When conditioners are used, they function in the acidic range (pH 2).
6. **Organic molecules**—Many compounds found in shampoo are organic. These are often related to the functional groups of the molecule. Two more common and important functional groups are the carboxyl group (–COOH) and the amino group (–NH2) that become involved in ionic bonding between the hair’s protein molecules.
7. **Emulsions**—Shampoos contain surfactants that, because they have polar and non-polar ends, can act as emulsifiers, allowing the hair oil (non-polar) to mix (emulsify) with the water (polar).
8. **Hydrogen bonding**—The article illustrates how hydrogen bonding figures into the interaction between the protein molecules of hair giving the hair volume through cross linkage. This linkage is accomplished through hydrogen bonding as well as ionic and covalent bonding.
9. **Covalent bonding**—Protein molecules in hair contain the amino acid cysteine, which has an –SH group. Two different protein molecules are able to bond covalently to each other through their –SH groups (each losing a hydrogen), forming a sulfur-sulfur bond).
10. **Ionic bonding**—Ionic bonding between protein molecules involves the ionic ends of two different protein molecules. The ionic ends are formed by one functional group such as an amino group (–NH2+2) and a carboxyl group (–COO-) linking.
11. **Anionic**—The hydrophilic end of a polar surfactant can have a charge, either positive or negative. Anionics (negatively charged) are the foaming and cleaning ingredients in shampoo.
12. **Cationic**—Cationics (positively charged) are the agents that help condition and add viscosity.

## Possible Student Misconceptions (to aid teacher in addressing misconceptions)

1. **“Some of the ingredients in shampoo can cause cancer.”** *Although an email rumor on the internet in 1998 suggested such an idea, the scientific cancer research community has not found any basis for making such a claim. Shampoo with its mixture of chemicals does not contain any carcinogens.*
2. **“All shampoos are the same.”** *A listing of ingredients from a variety of shampoos allows the student to see what chemicals are common to all shampoos and which ones are unique to a particular brand.*
3. **“Shampooing too often will damage hair.”** *Modern shampoos normally do not damage hair, and conditioners that make up part of the shampoo protect the cuticle against harm from brushing and combing. Depending on the person and the type of hair products used to wash the hair, some people find that the frequent washing may leave their scalp dry. But the hair itself is not damaged. There are moisturizers that can correct a dry scalp.*

## Anticipating Student Questions (answers to questions students might ask in class)

1. **“Why does shampoo contain formaldehyde—isn’t that a toxin or carcinogen?”** *The formaldehyde that may be found in shampoo is not an original additive in the manufacturing process but is produced through chemical reactions by other chemicals (preservatives) in the shampoo. The National Cancer Institute lists formaldehyde as a possible carcinogen with a variety of conditions for it to be carcinogenic*–*length of exposure time, concentration of the formaldehyde inhaled, etc. An explanation for the concern about formaldehyde in shampoo, given by a spokesperson for Johnson and Johnson Company is* that “Almost all living organisms contain formaldehyde [which is true–ed. note]. Our cells contain formaldehyde. The formaldehyde that occurs in our shampoo rinses off, biodegrades, and doesn’t turn into gas—shower water isn’t hot enough. There is more formaldehyde in one apple than in 14 bottles of shampoo.” ([*http://ideas.time.com/2012/08/22/the-real-lesson-of-formaldehyde-in-baby-shampoo/*](http://ideas.time.com/2012/08/22/the-real-lesson-of-formaldehyde-in-baby-shampoo/)) Also refer to the American Cancer Society’s detailed explanation of formaldehyde and its possible role as a carcinogen at

<http://www.cancer.org/cancer/cancercauses/othercarcinogens/intheworkplace/formaldehyde>.

1. **“Does shampooing strip away the natural color of our hair?”** *Although shampoos can strip away any coloring done to the hair over time, it has no effect on the natural color of your hair because the pigments that produce hair color* are primarily located in the hair bulb at the bottom of hair follicles. So it would be difficult for shampoo to interact with the imbedded hair follicle.
2. **“Can shampoos permanently change the texture of the hair, from curly to straight?”** *There are some shampoos that are designed specifically to change the hair texture, but the changes are only temporary.*
3. **“What are the benefits from using ‘Baby Shampoo’?”** *There are no benefits from using baby shampoo instead of regular shampoo other than the fact that it is a milder product. In a completely different application, baby shampoo is recommended for washing your dog or cat after they have been sprayed by a skunk! First apply tomato juice which is acidic (due to ascorbic acid, aka Vitamin C) or a 1:3 volume ratio of vinegar and water which chemically reacts with the mercaptans (a sulfur containing compound) in the skunk spray that produce the odor.*
4. **“What should I eat and drink for strong and healthy hair?”** *Basically, most health professionals today agree that you should simply eat a well-balanced diet. There are no special foods or supplements that need to be added to your diet.*
5. **“What ingredient in shampoo can prevent hair from tangling after washing? How does that work?”** *As mentioned in the article, shampoos contain conditioners. One function of the conditioner is to cover your hair with a slick surface to reduce friction and help keep strands from tangling together. The conditioner covers your hair in a light film that keeps each strand separate to increase body.*
6. **“What is dry shampoo?”** *Dry shampoo is essentially a powder based concoction that is usually used as an emergency substitute for regular liquid shampoo. Given that it is a powder means that it will probably leave the hair a bit dull because it will absorb the hair oils without replacing them. One explanation behind the use of—and issues with—dry shampoos (commercial products) is found at* [*http://www.wisegeek.com/what-is-no-rinse-shampoo.htm*](http://www.wisegeek.com/what-is-no-rinse-shampoo.htm)*. There are formulas for making your own dry shampoo. One site has six different formulas, depending on your particular reason for using a dry shampoo. Refer to* [*http://www.skin-care-recipes-and-remedies.com/homemade-dry-shampoo.html*](http://www.skin-care-recipes-and-remedies.com/homemade-dry-shampoo.html)*.*
7. **“Does lack of shampooing cause dandruff?”** *Dandruff is a condition produced by the accumulation of dead scalp cells and oils but its cause is not known. There is no agreement on the role of shampooing in preventing the dandruff condition. People with dry skin tend to get dandruff more often. And dry skin can occur more often in the winter when the air is drier and people are indoors with overly heated rooms.*
8. **“Is pH-balanced shampoo different from other shampoos that do not state they are pH-balanced? Is there any advantage to using such shampoos?”** *Most shampoos have a pH around 5.5 to 7. Cleaning agents such as soap & dishwashing detergent often have pH >9 and no sensible person uses these to wash hair. Assuming there is some reason to adjust the pH to that of skin or hair (hair is around pH 5), any benefit would be lost when you wash out the shampoo in gallons of water which has a pH around 6.5–7. Additionally, after shampoo, most people use a conditioner which can have a pH as low as 2.5 So even if you use a "pH acid balanced" shampoo, any supposed benefit is lost due to the washing process and is totally irrelevant due to the acid in the conditioner. So the term “pH balance” may be misleading.*

## In-class Activities (lesson ideas, including labs & demonstrations)

1. A complete lab exercise on shampoo can be found at <http://sciencenetlinks.com/lessons/the-chemistry-of-hair-care/>. This is a Science Net Link product of the American Association for the Advancement of Science (AAAS). The website includes all aspects of preparing and doing the exercise along with a series of student questions and an assessment section. Experimental procedures are included to test for pH of various shampoo products, testing hair samples in solutions with different pH values and evaluating the effect of the different pH solutions on the resilience of the hair samples which are examined by microscope. A handy worksheet is included for recording data. Also, there is a link to an online exploration of hair care. There is good teacher support for doing this lab activity.  
   If you do not have the time to do the lab prep, there is a commercial science kit about shampoo from Fisher Scientific at <http://www.fishersci.com/ecomm/servlet/fsproductdetail_10652_700239__-1_0>.
2. A reference that describes the effect of different pH values of shampoo on the hair follicle, that can be used in conjunction with the activity above, is found at <http://books.google.com/books?id=FjS4wttFPCgC&pg=PA226&lpg=PA226&dq=chemistry+of+hair+labs&source=bl&ots=ypKmL5KTT0&sig=YXXuYOxfw-Uk2LT-R_CZxxxS0-c&hl=en&sa=X&ei=Dy0HVP2LAdPJggSCuoGYDQ&ved=0CDwQ6AEwATgK#v=onepage&q=chemistry%20of%20hair%20labs&f=false>, page 228.
3. An extensive series of activities related to testing all aspects of soap, detergent and shampoo, such as the effect of pH on producing lather, can be found at <http://chemmovies.unl.edu/chemistry/labs/LABS12.html>. It is a very comprehensive series of lab activities with good teacher support, including data analysis questions and application of concepts. Included in this series of activities is measuring how well a shampoo produces lather in soft and hard water. Students produce soft water from hard by precipitating out the metal ions of Ca+2 and Mg+2.
4. A series of interesting questions that students can try to answer, true or false, might be a fun exercise to follow their reading of the *ChemMatters* article. Their responses are evaluated by the computer program, providing explanations about why it is true or false. Refer to [http://www.hair-science.com/\_int/\_en/toolbox/quizz.aspx?tc=ROOT-HAIR-SCIENCE^SO-STURDY-SO-FRAGILE^PRECONCEIVED-IDEAS&cur=PRECONCEIVED-IDEAS](http://www.hair-science.com/_int/_en/toolbox/quizz.aspx?tc=ROOT-HAIR-SCIENCE%5eSO-STURDY-SO-FRAGILE%5ePRECONCEIVED-IDEAS&cur=PRECONCEIVED-IDEAS).
5. Since surfactants in shampoo act as emulsifiers, a lab exercise to show the effect of emulsifiers on different types of solutions could be done. A well written series of lab exercises (seven) that deal with the basics of surfactants and emulsifiers is available from <http://www.juliantrubin.com/encyclopedia/chemistry/emulsion_experiments.html>. The lab guide includes necessary background on the classification of matter, emulsions, and the Tyndall effect. Lab activities include testing household products and surfactants, observing different conditions affecting surface tension, distinguishing between physical and chemical changes, saponification and making a hand cream.
6. Students are always impressed with demonstrating the reaction of polar and non-polar liquids to a charged rod. The standard hard rubber wand, balloon, or hair combs can be charged by induction (rubbing on fur, synthetic, silk, or wool cloth) and bringing the charged object close to a stream of liquid (easiest to use a burette for creating the stream). The same tested liquids can then be categorized as polar or non-polar. The same liquids can then be mixed in different combinations to see if the two liquids are soluble or insoluble, developing the rule of “like dissolves like” for polar and non-polar substances.

Here is a short (2:08) video showing the bending of water in the presence of a charged comb or balloon, from “Frostbite Theater” of Jefferson Labs, that very simply explains why water is bent: <https://www.youtube.com/watch?v=VhWQ-r1LYXY>.

1. Students might try making and testing “homemade” shampoos and conditioners. Refer to several shampoo recipes included in the Background section of this Teacher’s Guide. A reference for making a shampoo is found at <http://www.instructables.com/id/Homemade-Shampoo/>. A recipe for making a conditioner is found at <http://www.wikihow.com/Make-Hair-Conditioner-Using-Common-Ingredients>.
2. Students could read the list of contents on different shampoo containers that they bring into class—what substances, if any, are common to all the shampoos? Which of these substances is mentioned in the *ChemMatters* article? Using some of the references given in this Teacher’s Guide or going directly to a computer-based search, students could use the internet to find out the function of the different components of their shampoos.

## Out-of-class Activities and Projects (student research, class projects)

1. Students could research the actual manufacturing process for making shampoo. How much science goes into the process? A starting Web site is <http://www.madehow.com/Volume-3/Shampoo.html>. A complimentary YouTube video, made at a manufacturing facility, shows the essential ingredients for making a basic shampoo and what happens to them when they are added to the mix.
2. If not done as a class lab activity, students could produce their own shampoos and test them on themselves. But this should only be done with parental approval and supervision by a teacher. Their evaluation of the performance of each shampoo along with the formulas could be presented to the class.
3. A student could make a hair hygrometer for measuring the humidity in the air. This is a design from the 18th C.! Refer to the following website for how to construct the device. <http://www.exploratorium.edu/exploring/hair/hair_activity.html#test>. Background information and some activities with the device are included.

## References (non-Web-based information sources)



**30 Years of *ChemMatters***

Available Now!

**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013 and all available Teacher’s Guides, beginning February 1990). 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)**. Scroll about half way down the page and click on the *ChemMatters* DVD image at the right of the screen to order or to get more information.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online on the same Web site, above. Simply access the link and click on the “Past Issues” button directly below the “M” in the *ChemMatters* logo at the top of the Web page.**

Baxter, R. pH and Shampoo. *ChemMatters* **1983**, *1* (2), pp 8–9. In the April 1983 issue of *ChemMatters* is an informative article on the behavior of hair when it is washed with shampoo. There is a good discussion about the role of surfactants and pH on the structure of hair at the cellular and molecular level.

Baxter, R. Permanent Waves. *ChemMatters* **1993**, *11* (2), pp 8–11. An article in the 1993 issue deals with what happens at the cellular and molecular level when various chemicals are applied to hair to create waves. The illustrations concerning bonding (making and breaking) and the structure of hair follicles are a useful reference.

Fruen, L. Natural, Braided, Bleached, Colored, Straight, and Curly Hair…Thanks to Chemistry. *ChemMatters* **2008**, *26* (3), pp 15–17. Doing things to hair other than washing requires the right chemicals—think of conditioners, styling gels, and hair dyes. The way in which hair responds to these chemicals is well documented in this 2008 article. There is also an extensive Teacher’s Guide available for that article.

Raber, L. Hair Color: Chemistry to Dye For. *ChemMatters* **2002**, *20* (2), pp 10–11. For those interested in the chemistry of dyeing hair, an article in April 2002 details the materials used for coloring the hair.

Banks, P. A New Kind of Bad Hair Day, *ChemMatters* **1998**, *18* (4), pp 9–10. There might be some interest by students in how hair samples are used to test for various chemicals that a person has been exposed to (lead in the air) or consumed. An article in the December 1998 issue describes the various kinds of testing kits used to detect different chemicals in hair. The author also points out some of the difficulties and problems (ethical) with testing hair for drugs and other regulated substances.

Meadows, R. Buried in Ice. *ChemMatters* **1994**, *12* (2), pp.4–7. A related issue is testing for lead, using hair samples. This is a particularly interesting article that details the present day investigation into the 1847–48 deaths of a number of Arctic explorers who were found to be well preserved in the ice. Doing chemical analysis of the men’s hair revealed high levels of lead, which may have contributed to their death along with disease and over-exposure to the cold. It is a good detective story of sorts, utilizing chemical and biological analysis.

## Web Sites for Additional Information (Web-based information sources)

**More sites on the function of the different components of shampoo**

A number of references concerning the different components in shampoo, and their function, include the following:

<http://sci-toys.com/ingredients/shampoo.html> and

<http://www.theepochtimes.com/n3/616834-shampoo-ingredients-you-want-to-avoid/>.

The second reference contains useful descriptions about the various components in shampoo and the author’s bias, perhaps, about what components to avoid when selecting a shampoo. A similar reference with the same bent is found at <http://www.details.com/blogs/daily-details/2013/04/the-dirt-on-shampoo-ingredients-8-tips-on-what-to-look-for-and-what-to-avoid.html>.

A dictionary of terms for the ingredients in shampoo can be found at <http://www.schwarzkopf.com/sk/en/home/hair_care/protecting_pampering/care_tips/dictionary_hair_care_ingredients.html>.

An extremely detailed document (scientific in chemical terms) that is all about hair and how the various shampoo chemicals operate at the molecular level (of hair structure) is found at <http://wwwcourses.sens.buffalo.edu/ce457_527/ce457_pro/g8_doc.htm>.

The American Chemical Society’s flagship publication *Chemical and Engineering News* periodically publishes a feature called “What’s that Stuff?” These one-page articles describe the chemistry behind an everyday object—such as pencils, or bubble gum—or shampoo: <http://pubs.acs.org/cen/whatstuff/stuff/8015sci3.html>. (Giroux, R. What’s That Stuff? Shampoo. *Chem. Eng. News* **2002**, *80* (15), p 42)

**More sites on** **how to make your own shampoo**

There is a plethora of web sites that advise the do-it-yourselfers on making one’s own shampoo with some explanations for why a particular ingredient is used. See the following sites for instructions:

<http://wellnessmama.com/3701/natural-shampoo/>

<http://www.goodhousekeeping.com/beauty/natural-shampoo-recipe-460409>

<http://www.instructables.com/id/Homemade-Shampoo/>. The last site is the source of some recipes quoted in the Background section of the Teacher’s Guide.

**More sites on** **hair structure at the microscopic level**

An extensive reference that includes many drawings and photomicrographs of the hair follicle is found at <http://www.chem.sc.edu/analytical/chem107/lab4_032205.pdf>.