



**Tools and Resources**

***“Fighting Frizz:   
How Chemistry  
Solved a Bad Hair Day”***

April/May 2019

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

**Teacher’s Guide:**



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**Tools and Resources**

***“Fighting Frizz: How Chemistry  
Solved a Bad Hair Day”***

**April/May 2019**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Intermolecular forces** | The discussion of sodium lauryl sulfate’s action in water supports lessons about hydrogen bonds and polar and nonpolar attractive forces between molecules. |
| **Acids and bases** | The structural formula of glycolic acid, the principal ingredient in the Lubricity shampoo, can be used when talking about organic acids. The effect of the acid on hair provides a practical application of acids in commercial products. |
| **Oxidation and reduction** | The formaldehyde used in keratin treatments can be used as an example of a reducing agent. The definition of reducing agent in the article supports lessons on oxidation and reduction, as does the reaction of breaking and re-forming disulfide bonds in hair, illustrated in Figure 1. |
| **Organic chemistry** | During a unit on organic chemistry, the molecules discussed in the article provide examples of an aldehyde, an organic acid, and long-carbon-chain alkyl groups (found in surfactants). |
| **Green chemistry** | To emphasize green chemistry principles throughout the school year, you can point out to students that Clark was concerned that his product should be safe and contain safe ingredients. |
| **Biochemistry** | The discussion of disulfide bonds in hair keratin can be used while teaching about these bonds in proteins. Also, the explanation of quinoa protein being spliced into segments of hair provides an example of engineered protein repair. |
| **Engineering & problem-solving** | Clark’s trial and error process, employed while developing the anti-frizz shampoo, provides an example of product engineering and problem-solving while teaching about those components of scientific discovery. |

# Teaching Strategies and Tools

## Standards

* Links to **Common Core Standards for Reading**:
  + **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
  + **ELA-Literacy.RST.9-10.5:** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
  + **ELA-Literacy.RST.11-12.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
  + **ELA-Literacy.RST.11-12.4:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
* Links to **Common Core Standards for Writing**:
  + **ELA-Literacy.WHST.9-10.2F:** Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
  + **ELA-Literacy.WHST.11-12.1E:** Provide a concluding statement or section that follows from or supports the argument presented.

## Vocabulary

* **Vocabulary** and **concepts** that are reinforced in this issue:
  + Structural formulas
  + Proteins
  + Hydrogen bonding
  + Environmental impacts of personal and societal decisions
  + Periodic properties
  + Nuclear chemistry
  + Equilibrium
  + Green chemistry
* Consider asking students to read “Open for Discussion: Paper vs. Pixel” on page 4 before or after they read “Celebrating Paper!” to help them understand the complexity of making decisions about whether to use paper or electronic versions of paper products such as e-textbooks.
* The theme of Chemists Celebrate Earth Week (CCEW) this year is “The Chemistry of Paper,” so you and your students can check out some of the activities that can be found at the website found on the back cover.
* The engaging video “Is it OK to pee in the pool?” (see p. 18), produced by ACS, has excellent chemistry information.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles, and what they would like to explore further.
* Ask students if they have questions about some of the issues discussed in the articles.

# Possible Student Misconceptions

1. **“Hydrogen bonding occurs when hydrogen is bonded to another atom on the same molecule. Like the hydrogen atoms bonded to oxygen in a water molecule.”** Students often develop a misunderstanding about hydrogen bonds. Some will label the bond between hydrogen and oxygen in a water molecule as a hydrogen bond. Literally, it *is* a hydrogen bond, just not the one chemists are referring to when they talk about *hydrogen bonding*. It is important to emphasize that a “hydrogen bond” is an electrostatic attraction between neighboring molecules. When hydrogen is covalently bonded to a highly electronegative element, the hydrogen electron is attracted to the more electronegative element, exposing the positive charge of the hydrogen nucleus. The exposed hydrogen nucleus is attracted to the negatively charged electrons of an oxygen, nitrogen, or fluorine atom in neighboring molecules, causing an attraction between and an alignment of the two molecules. This type of bonding is illustrated with dashes between the hydrogen atoms of a water molecule and an oxygen atom in a sulfate group of sodium lauryl sulfate in the article insert, “How Shampoo Cleans Your Hair”.
2. **“Intermolecular forces are the forces within a molecule.”** Sometimes students may interpret intermolecular forces as the forces that hold an individual molecule together. Perhaps “inter” is being heard as “inner”. You may be able to help students with this by using the example of the “***inter*state highways**” that connect one state to neighboring states, emphasizing the prefix *inter*-. “Intermolecular forces” then, are the attractions that connect one molecule to neighboring molecules. Attractions between the atoms *in* the molecule are the *intra*molecular forces and are stronger than forces between molecules.
3. **“Keratin treatments contain formaldehyde.”** Technically, keratin treatments do not contain formaldehyde, as formaldehyde is a gas. However, they may contain compounds that, when exposed to water, react to release formaldehyde. The formaldehyde-producing compounds often found in keratin treatments are methylene glycol, formalin, methanol, and methanediol. Products that contain some of these compounds could accurately advertise themselves as formaldehyde free. Formalin is formaldehyde dissolved in water, with methanol added to prevent polymerization. Glyoxylic acid can be used to replace formalin (see #4 below), though treatments that use glyoxylic acid last for only two to three months, while the treatments that use the more toxic ingredients last four to six months.
4. **“Keratin treatments are hair-straightening treatments.”** Keratin treatments and hair-straightening treatments are two different processes.

Hair-straightening treatments are similar to permanents. In this type of treatment, the hair is soaked with ammonium thioglycolate, which breaks the disulfide bonds in the hair. With the hair relaxed, it is then straightened with a flatiron and a solution of hydrogen peroxide is added that encourages the disulfide bonds in the hair to reform while the hair is straight. A hair-straightening treatment is permanent for the hair that is treated. As the hair continues to grow outward from the follicle, however, it will “grow in” with its original curliness, creating an awkward line between the curly hair and the straight hair.

In keratin treatments, a serum containing keratin is applied to the hair after the disulfide bonds have been relaxed with a solution containing formalin or a similar reducing agent. Many solutions used for the relaxing step contain compounds that give off the gas formaldehyde as the hair dries. Formaldehyde is a suspected carcinogen, so some treatments use glyoxylic acid to relax the hair. But, as mentioned in question #3 above, these treatments don’t provide as long-lasting results as the treatments that use the formaldehyde-forming compounds. After the hair has been coated with keratin serum, it is treated with a flat iron that activates the keratin, laminating it to the strands of hair. The keratin wears off with time, so the hair slowly resumes its original curliness. With keratin treatments, the hair maintains more of its original shape; it is just more manageable and holds a straighter style between washes.

1. **“Hair is composed of living cells that can repair themselves with the use of the right product.”** Reading the claims of many of the hair products on the market may give consumers the impression that hair is a living organism. Several ingredients in shampoos are listed as nutrients and, indeed, include some vitamins and minerals. However, hair is nonliving material just like fingernails. The only living portion of hair is the follicle in the scalp. Hair has no biochemical activity and hence is considered dead. To grow healthy hair requires *consuming* a diet with adequate protein, vitamins, and minerals—not just layering them on the hair surface.
2. **“Air drying is healthier for hair than blow drying.”** While blow drying causes more damage to hair’s surface, air drying can create damage deeper within the strands. The strands of hair swell when they get wet. When they remain swollen for the two hours it typically takes hair to air-dry, the pressure put on the delicate proteins that hold the hair intact can damage the strand’s internal structures. The best way to dry your hair is to blot it with a towel and let it partially air dry before using a hair dryer, set on a low-temperature setting, to finish drying your hair. (<https://www.prevention.com/beauty/hair/a20442345/the-healthiest-way-to-dry-your-hair/>)
3. **“You should brush your hair 100 strokes per day.”** Brushing benefits your hair by distributing the oils, located near the hair follicles, throughout the hair. But you do not need to brush your hair 100 strokes every day to maintain healthy hair. Too much brushing is actually bad for your hair. Brushing can create friction on hair leading to cuticle damage, breakage, and frizz. You should only brush your hair enough to get the tangles out and smooth it out when needed. A wide-tooth comb or a brush with soft bristles is the best tool to use for hair maintenance.

# Anticipating Student Questions

1. **“How do permanents for curling your hair differ from hair-straightening treatments and keratin treatments?”** Permanents for curling hair involve the same chemicals as those used in straightening hair. The difference between the two treatments lies in how the hair is shaped when the ammonium thioglycolate, a reducing agent, is applied to the hair. The ammonium thioglycolate relaxes the hair by breaking the disulfide bonds between the hair’s keratin molecules. In a perm (or “permanent wave”), the hair is wrapped on curlers when the ammonium thioglycolate is applied, while with hair straightening, the hair is pressed between the plates of a heated flat iron to restructure the hair into a straighter shape. The next step in both processes is the application of an oxidizing agent such as hydrogen peroxide to the hair, to reconstitute the disulfide bonds so that the hair will maintain the desired shape. Keratin treatments use a compound to relax the disulfide bonds in the keratin in order to allow more keratin to be added to the hair. A hot flat iron is then used to laminate this keratin into the hair strands. Keratin treatments are believed to be safer for the hair, since the natural structure of the hair is not being altered as drastically and more protein is being added to the hair.
2. **“In the hair-straightening treatments, why does the hair bond in a straightened shape?”** In hair-straightening treatments, the hair bonds in a straightened shape, because it is physically pulled and arranged into that shape while the disulfide bonds in the strands of hair are broken as hydrogen ions, are added across the broken bond. This is referred to as relaxing the hair. Once the hair is in the desired straightened shape, hydrogen peroxide is placed on the hair. This causes the hydrogen to be removed from the sulfur in the cysteine molecules of the keratin, so that the disulfide bonds within the hair can reform, keeping hair straightened.

**Hair Relaxing Step**

Keratin-S--S-keratin + 2 HS-CH2CO2NH4 --> –HO2CH2CS-SCH2CO2H

curly hair ammonium thioglycolate + 2 NH3 + 2 HS-keratin

relaxed hair

**Hair Rebonding Step**

2 Keratin-SH + H2O2 --> Keratin-S--S-keratin + 2 H2O

relaxed hair straightened hair

(<https://is.muni.cz/el/1431/podzim2013/C3804/The_chemistry_of_perming___rebonding.pdf>)

1. **“What is the purpose of the heat used in a keratin treatment?”** Heat is used in the keratin treatments to laminate the added keratin onto the surface of the hair, similar to how a laminating machine seals the plastic film over and around a poster or piece of paper.
2. **“What exactly is the purpose of hair conditioners? How do they work?”** Conditioners reduce the friction between hair strands, which makes brushing and combing easier, thereby avoiding additional damage to the hair. It also improves the feel, appearance, and manageability of hair. Some conditioners also contain sunscreens to protect the hair during exposure to the sun. There are a lot of electrostatic attractions involved in the chemistry of hair conditioning. The cysteine molecules that compose keratin are mildly acidic. When hair is washed, these molecules lose hydrogen atoms, become deprotonated, creating a negative charge in the cuticles. As like charges oppose each other, this makes the cuticles stand up. Conditioners are mildly acidic and contain positively charged quaternary ammonium compounds that can attach to the hair via electrostatic attractions. The negatively-charged cuticles become neutral as they bond with either the quaternium cations or the hydrogen ions from the acid in the conditioner, and they lay flat, tight against one another. The quaternium cations have a long hydrocarbon backbone that lubricates the surface of each hair and facilitates hair combing. This surface coating of cationic groups that repel each other results in hair that resists tangling. <https://en.wikipedia.org/wiki/Hair_conditioner>
3. **“Some of my friends are only using conditioner to wash their hair. It’s called   
   co-washing. What does that do for your hair?”** Co-washing is where you skip the shampoo and wash your hair with conditioner to avoid stripping the natural oils from the hair. It allows natural oils to cleanse and condition the hair and scalp, and some think this is healthier. After using only conditioner, hair is not fluffy or fly away and is easier to control. Some say their hair feels softer and silkier from using only conditioner. The “down side” is that the hair feels dull and heavy and sometimes may have a musky smell. If too much oil collects around the hair follicle, the hair will not grow as fast. This practice works best for people with thick, coarse, dry, or curly hair.
4. **“How can defects in the hair cuticle be negatively charged?”** Damaged cuticles usually have hydrogen atoms that have been knocked off of the cysteine molecules that make up hair keratin. Losing a hydrogen atom causes the molecule to become negatively charged. Cysteine molecules are mildly acidic and, when hair is washed, these groups deprotonate, leaving a negative charge.
5. **“Are shampoos and conditioners bad for the environment?”** Shampoos and conditioners have many ingredients that can prove harmful to sea life, plants, and people. Once these chemicals get into the water system and into the air we breathe, it is not long until they can be detected within wildlife and humans. Waste-water treatment plants are not equipped to remove most of these chemicals from the water, so they find their way into our drinking water. Some of the most problematic chemicals are shown in the table below.

|  |  |
| --- | --- |
| Compound | Action |
| Sodium laureth sulfate | This surfactant in shampoos is a skin irritant in humans and a mutagen in some wildlife. |
| Ammonium chloride | This is a respiratory and eye irritant. |
| Methylchloroisothiozolinone | This antibacterial, antifungal preservative is a skin irritant, an allergen, and a toxin to the immune system. |
| Parabens | These compounds have been linked to breast cancer. |
| Triclosan | This antibacterial agent is toxic to aquatic life and has been found in the bodies of fish and in human breast milk. |
| Phthalates | This family of 120 industrial chemicals interferes with hormones and is associated with reproductive problems in men and wildlife. These substances also show bioaccumulation. |

Some of the compounds in shampoos and conditioners, as well as other personal hygiene products, emit volatile organic compounds (VOC’s) when exposed to the air. These create a “personal plume” that follows a person out the door in the morning. VOCs in the presence of sunlight react with nitrogen oxides in the air to form ozone, a type of pollution regulated because of its effects on air quality and human health. Decamethylcyclopentasiloxane, or D5 siloxane for short, is one of these compounds added to products like shampoos, lotions, deodorants, and hair gels, to make them feel smooth and silky. Recently, environmental researchers from the University of Colorado found evidence of air pollution caused by these volatile organic compounds. They detected a spike of siloxane in the air during the morning rush hour. Thinking that it must be coming from automobile exhaust, the scientists conducted isolated tests on automobile exhaust but did not find siloxane present. Since the spike in siloxane occurred during the morning rush hour, a time where many people have just finished using many of their personal-care products, the scientists hypothesized that the source of the pollutants they detected was the “personal plumes’ of VOCs. Environmentally-friendly products use plant oils and natural fragrances in place of the many petroleum products currently found in the majority of personal hygiene products. (<https://www.sciencedaily.com/releases/2018/04/180430131828.htm>)

# Activities

**Labs and demos**

**“Soap vs Shampoo Surfactant Lab”:** In this engineering lab, students make their own shampoo and soap and then conduct tests for pH, viscosity, surface tension, and the ability to form suds for each product in different water environments. This activity can be simplified by having students use commercial soaps and shampoos, rather than make their own. (<https://www.teachengineering.org/activities/view/usm_surfactant_activity1>)

**“Intermolecular Forces and Physical Properties” demos:** Using alcohol, acetone, and water, the teacher discusses differences in polarity, intermolecular forces, surface tension beading, and miscibility of each liquid, while demonstrating the phenomenon. A demonstration of the polarity differences of blue food coloring and red food coloring provides a strong visual of molecular preferences based on polarity. (Access is restricted to AACT members, but the article will be available for free until June 1, 2019, at <https://teachchemistry.org/classroom-resources/intermolecular-forces-and-physical-properties>.)

**Media**

**“How Does Shampoo Work?” video (3:38):** This ACS *Reactions* video discusses the ingredients in shampoos, especially the sulfates, and describes their action in cleaning hair. (<https://www.acs.org/content/acs/en/pressroom/reactions/videos/2016/how-does-shampoo-work.html>)

A sequel to the above video, **“What Happens if You Stop Washing Your Hair?” (3:15),** gives information about the ingredients in conditioners and discusses the “no poo” craze called   
co-washing, where people skip the shampoo and just wash their hair with conditioner. (<https://www.youtube.com/watch?v=aTRZ-Up1iWA>)

**“Hair Styling Products: A Scientific Combination”, video (4:23):** A Loreal product scientist discusses the development of hair products that create different effects on the hair. The research centers on using polymers to create the company’s different products. (<https://www.youtube.com/watch?v=5WnkDK8SAI4>)

**Lessons and lesson plans**

**“Bad Hair Days? Chemistry to the Rescue”:** This site contains extensive background information for teaching a unit about proteins that uses the physical and chemical composition of hair, as well as the chemistry of perms and hair-straightening treatments, as a vehicle to deliver the lessons. The lessons include demonstrations, a mini-lab, a lab investigation using hair samples, and instructions for the students to make a foldable about hair treatments. (<https://teachers.yale.edu/curriculum/viewer/initiative_11.05.04_u>)

**“The Chemistry of Hair Care”:** The activities in this lesson are planned to help students answer the central question, “How does understanding the chemistry of hair care, including the role of pH, help in the development of better hair-care products?” In this three-part lesson, students measure the pH of different shampoos, analyze the effects of acidic and basic solutions on strands of hair, and read and answer questions about the chemistry of hair.

(<http://sciencenetlinks.com/lessons/the-chemistry-of-hair-care/>)

**Projects and extension activities**

**“Exploring Intermolecular Forces”:** This activity includes teaching notes and diagrams and could be used as an inquiry lab prior to teaching intermolecular forces. Students grade the cleaning effectiveness of substances based on the results of several analyses. (Access is restricted to AACT members, but the article will be available for free until June 1, 2019, at <https://teachchemistry.org/classroom-resources/exploring-intermolecular-forces>.)

**“Are Designer Shampoos Worth It?” project:** This site provides an idea and a structure for students to complete a longer-term experiment with hair-care products. Students recruit volunteers to use a variety of products and provide strands of hair for the student researchers to test and analyze under a microscope in order to determine the efficacy of each hair product.

(<https://www.education.com/science-fair/article/designer-shampoos/>)

# References

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

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



In “pH and Hair Shampoo”, author Baxter discusses the effects of pH on the three different types of bonds—disulfide, salt bridge, and hydrogen—found in hair, and how their effects apply in the manufacture of shampoos and rinses. (Baxter, R. pH and Hair Shampoo. *ChemMatters.* 1983, *1* (2), pp 8–9)

This article provides illustrations of bonding changes that occur in hair during a perm that are useful in explaining what happens at the cellular and molecular level when various chemicals are applied to hair to relax and reshape it. (Baxter, R. Permanent Waves. *ChemMatters.* 1993, *11* (2), pp 8–11)

This article presents an overview of several hair products and how the chemicals they contain interact with hair protein to achieve the desired effect. (Fruen, L. Natural, Braided, Bleached, Colored, Straight, and Curly Hair…Thanks to Chemistry. *ChemMatters.* 2008, *26* (3), pp 15–17)

The Teacher’s Guide to the October 2008 *ChemMatters* article above contains instructions for making a hair hygrometer.

Author Bruzek writes about how surfactant molecules in shampoos clean hair, using several diagrams of the cleaning process to illustrate her work. There is a full-page graphic about sodium lauryl sulfate following the article that could be used as a poster. (Bruzek, A. Shampoo: From Lab to Shower. *ChemMatters*. 2014, *32* (3), pp 17–18)

The Teacher’s Guide to the October 2014 *ChemMatters* article above contains additional information on the function and safety of the chemicals used in shampoos and conditioners. Recipes for students to use to make their own shampoo are included, as well as links to additional recipes and instructions.

This article contains information about parabens in regards to their safe use in personal care products. (Gmurczyk, M. Parabens: A Source of Concern. *ChemMatters*. 2015, *33* (2), pp 8–9)

Triclosan, an antibacterial agent that is added to many shampoos, soaps, toothpastes, and lotions, may interfere with some hormones, as well as alter the normal bacterial flora. This article reviews some of the recent reports on this substance. (Harper, K. Bacteria Buster Triclosan Kills Bacteria but Is It Safe? *ChemMatters*. 2015, *33* (4), pp 13–15)

The Teacher’s Guide to the December 2015 *ChemMatters* article above includes extensive information and links to the various studies, both human and environmental, that have been conducted about triclosan.

# Web Resources for More Information

**Hair-care documentary**

“Horizon: Hair Care Secrets” (58:38) is a documentary about hair care, not only about the chemistry of the products used for its maintenance but also the use of hair transplants and dyes to counter the natural changes that occur in hair over time.

(<https://vimeo.com/209603274> )

**Keratin treatments**

“The Everything Guide to Keratin Treatments” describes the difference in hair-straightening techniques. The site discusses keratin treatments, where keratin is bonded to hair; chemical relaxers, which are like permanents; and Brazilian blowouts, which are temporary.

(<https://www.thecut.com/2018/05/everything-to-know-about-keratin-treatments.html>)

“8 Things to Know About Keratin Treatments” describes the chemistry of these treatments and addresses the use of compounds that produce formaldehyde when heated in—treatments that claim to be formaldehyde free. It also explains some chemistry of glyoxylic acid alternatives. (<https://www.allure.com/story/keratin-hair-smoothing-treatment-how-to>)

**Permanent hair-straightening**

This site explains the difference between hair-straightening and keratin treatments.

(<https://www.stylecraze.com/articles/hair-smoothing-vs-hair-straightening/#gref>)

In “Hair Straightener”, the author addresses the chemistry behind the Brazilian blowout, the Japanese thermal straighteners, and the alkaline-relaxer hair treatments. (<https://cen.acs.org/articles/88/i45/Hair-Straighteners.html>)

**Shampoo surfactants**

“How Shampoo Works” contains information on shampoo as well as a brief (1:10) video about busting four shampoo myths.

(<https://www.thoughtco.com/how-shampoo-works-607853>)

This entry (“Shampoo”) in *How Products are Made* goes through the steps involved in producing a shampoo. It discusses in detail the purpose of each of the ingredients used to make shampoo.

(<http://www.madehow.com/Volume-3/Shampoo.html>)

**Hair conditioners**

Besides relating the history of conditioners and how they are classified, this site contains a good list of conditioner ingredients and their function:

<https://en.wikipedia.org/wiki/Hair_conditioner>.

How does hair conditioner work? Explains the chemistry involved in hair conditioners and conditioning shampoos.

(<https://scienceline.org/2014/01/how-does-hair-conditioner-work/>)

**Recipes to make your own shampoo or conditioner**

This site gives ten different recipes for making your own shampoo, even including one for a no poo shampoo.

(<https://www.instructables.com/id/Homemade-Shampoo/>)

Use simple ingredients from your kitchen or garden to make six hair conditioners.

(<https://food.ndtv.com/beauty/6-natural-hair-conditioners-for-every-hair-type-you-can-make-at-home-1810325>)

**Environmental impact of shampoo and conditioners**

Scientists from the University of Colorado, while studying air pollution, discovered a spike in the VOC siloxane in the atmosphere during morning “rush hour”, possibly from personal-care products such as shampoos, lotions, and deodorants.

(<https://inhabitat.com/your-shampoo-and-deodorant-cause-as-much-pollution-as-your-daily-commute/>)

“Polluting the Water with Toothpaste, Shampoo, and Drugs” addresses the pollution of water with household chemicals found in soaps, shampoos, cleaning agents, and drugs. Many of these compounds have not been thoroughly studied and are not required to be removed from drinking water.

(<http://www.invw.org/2012/09/12/new-pollutants-1313/>)

**Lubricity Web site**

Not only is Alden’s and Dr. Clark’s story retold on this site, but the chemistry of the product they developed is also presented.

(<https://lubricitylabs.com/pages/the-lubricity-system>)

**General hair-care chemistry**

“Better Hair Through Chemistry” is an article written for high school students that discusses the chemistry of hair and several types of hair products. It addresses the hydrogen bonds and disulfide bonds found in hair and explains how they are affected by changes in pH.

(<http://www.exploratorium.edu/exploring/hair/>)

“Hair Cosmetics, An Overview” reviews the ingredients and action of shampoos, conditioner, hair-straightening products, and hair dyes. The Brazilian keratin treatment is also reviewed.

(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4387693/>)