

Goal: to investigate a real world application of green chemistry

Massachusetts State Standards Met:

SIS3. Analyze and interpret results of scientific investigations.

SIS4. Communicate and apply the results of scientific investigations.

This document is to be used to find Green Chemistry topics to complete a 3, 2, 1 summary assignment . Each of these resources exemplify a more responsible way of practicing and thinking about chemistry and the impact it has on the world around you. Enjoy!

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| **Resource** | **Chemistry Content Covered** | **Description** |
| ***General Resources:***  ***browse and choose your own topic*** |  |  |
| Choose an article from the ChemMatters Sustainability page  <http://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/articles-by-topic/sustainability.html> | varies |  |
| Choose an article from the Chemical & Engineering News Green Chemistry page  <http://cen.acs.org/collections/greenchem.html> | varies |  |
| Choose an article from the Chemical & Engineering News Sustainability page  <http://cen.acs.org/collections/sustainability.html> | varies |  |
| Choose an article from National Public Radio “Science Edition”environmental page  <http://www.npr.org/sections/environment/> | varies |  |
| Choose an article from Scientific Americans Energy and Sustainability page  <http://www.scientificamerican.com/energy-and-sustainability> | varies |  |
| Watch a video or read an article on the Greenovate website.  <http://greennovate.org> | varies | A website with many resources and videos to watch and learn more about sustainability. |
| Watch a video or read an article on the Greenovate website.  <http://www.storyofstuff.org> | varies | A website devoted to educating the public on how stuff is made, how much we use and where it goes. |
| ***Specific Resources:***  ***articles or videos on a particular topic*** |  |  |
| Watch **The Majestic Plastic Bag**  <http://www.youtube.com/watch?v=GLgh9h2ePYw>  Then Read: Boy Discovers Microbe that Eats Plastic  Mother Nature Network  [http://www.mnn.com/green-tech/research-innovations/blogs/boy-discovers-microbe-that-eats-plastic#](http://www.mnn.com/green-tech/research-innovations/blogs/boy-discovers-microbe-that-eats-plastic) | environmental science,  catalysis | The video is a play on words regarding plastic bags. The video in the assignment in combination with the article aims to get students to think about everyday items that pose health and safety risks and how we can properly dispose of them in an environmentally friendly way. |
| Watch: **The Story of Stuff**  <http://www.youtube.com/watch?v=9GorqroigqM> | sustainability | This video is a great way to think about “stuff”. How much you have, where it comes from and where is goes. |
| Read: Green Graphine Bandaids  <http://www.rsc.org/chemistryworld/2013/07/antimicrobial-graphene-band-aid> | allotropes, nanotechnology | Graphene is an allotrope of carbon that could be used as an antimicrobial material for band-aids. (1) |
| Read: ‘Super sand’ for better purification of drinking water  ACS News Weekly Service PressPac Aug 03, 2011  <http://www.acs.org/content/acs/en/pressroom/presspacs/2011/acs-presspac-august-3-2011/super-sand-for-better-purification-of-drinking-water.html> | sustainability | The article explores a sustainable and environmentally friendly way to filter water. |
| Read: Open for Discussion: Goodbye Plastic, Hello Edible Wrappers-or Nothing at all!  ChemMatters, April 2013  <http://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/archive-2012-2013/edible-wrappers.html> | environmental science | An eco friendly way to package food. |
| Watch: **How NASAKeeps Tabs on Air Pollution from Space**  [**http://www.youtube.com/watch?v=zSV6qz0QLuw#at=61**](http://www.youtube.com/watch?v=zSV6qz0QLuw#at=61) | innovations | Thinking about how we can effectively monitor air quality. |
| Read: A New Energy-Saving Pigment Comes Out of the Blue ACS News you can use  <http://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/news/blue-pigment.html> | environmental science | A new environmentally friendly pigment helps students understand the impact and vast use of pigments. |
| Read: “Eco-Design” and all of the subtopics under the “Eco-design” tab. <http://sustainabledevelopment09.loreal.com/innovation/green-chemistry.asp> | consumer products | What chemicals are in your make up? See how the cosmetics company Loreal uses green chemistry. (2) |
| Read: “Scientists Developing Self-Healing Concrete with Micro-Capsules and Bacteria.”  <http://inhabitat.com/scientists-developing-self-healing-concrete-with-micro-capsules-and-bacteria/> Related article: “New Biological Conrete Absorbs CO2 adn PRovides Thermal Insulation.” <http://www.jetsongreen.com/2013/01/new-biological-concrete-absorbs-co2-and-provides-thermal-heat-insulation.html> | innovations, chemical reactions | Can cracked concrete heal itself? Scientists are developing a way to use microencapsulated bacteria to help repair cracks in concrete. (3) |
| Articles & video: 1.Read: [“Biomimicry: Mother Nature as a 3-D Printer?”](http://www.google.com/url?q=http%3A%2F%2Fwww.jetsongreen.com%2F2013%2F01%2Fnew-biological-concrete-absorbs-co2-and-provides-thermal-heat-insulation.html&sa=D&sntz=1&usg=AFQjCNFF__iDSCz6tUJ9rRdIks3xEsniqQ)[http://www.triplepundi](http://www.jetsongreen.com/2013/01/new-biological-concrete-absorbs-co2-and-provides-thermal-heat-insulation.html)[t.com/2013/07/biomimicry/](http://www.triplepundit.com/2013/07/biomimicry/)2. Watch: “6,500 Live Silkworms 3-D Print an Incredible Dome.” <http://mashable.com/2013/07/13/silkworms-3d-print-dome/>  3.Watch : “Mashable” <http://bcove.me/du7odsac> | innovations, biomimicry | The MIT Media Lab is developing 3-D printing technology. Silk worms are being used to help study conditions that affect patterns and density of the 3-D product. (4) |
| Read: “BioBag and the Environment.”  <http://www.biobagusa.com/mater_bi.htm> | innovations, consumer products, polymers | If biodegradable plastic exists, why are we still using “regular” plastic bags? (5) |
| Watch: “Green Chemistry.” http://www.cmu.edu/campaign/multimedia/environment/green\_chemistry.html | innovations, chemical reactions | [Green chemistry can be used to clean water using](http://www.cmu.edu/campaign/multimedia/environment/green_chemistry.html) a catalyzed reaction with hydrogen peroxide. (6) |
| Read: “Sustainability” and all the subheadings under the “Sustainability” tab.  <http://www.diamondpackaging.com/green/materials/plastic.htm>  [www.kpfilms.com](http://www.kpfilms.com/) | innovations, polymers | Think of all the packaging our society uses. Green chemistry technology can replace fossil fuel-based material with up to 30% plant based material. (7) |
| Watch: “How Plastic Bottles Can Light Up Darkness.”  **htt**[p://wimp.com/lightenup/](http://wimp.com/lightenup/) | innovations, energy | Solar bottle lights provide 55 Watts of free and clean light. (8) |
| Read: [“The Sefose Product Story.”](http://www.google.com/url?q=http%3A%2F%2Fwimp.com%2Flightenup%2F&sa=D&sntz=1&usg=AFQjCNFPlt73HBKvKTsbf8SPiMyT0CpkAA)  <http://www.pgsefose.com/sefose-product-story.html> | polymers | Proctor and Gamble has developed a non-toxic wood finish based on a polymer made of sucrose and fatty acids. (9) |
| Watch: **The Secret Lives Of Clothes**  [**http://greennovate.org/the-secret-lives-of-our-clothes**](http://www.google.com/url?q=http%3A%2F%2Fgreennovate.org%2Fthe-secret-lives-of-our-clothes&sa=D&sntz=1&usg=AFQjCNF2eEnHsyt5fu8szPxooxgZqstfNw) | sustainability  environmental science | There’s a price tag that’s being hidden from us everyday. Not the one that tells us how much money to pay but the underlying costs of every outfit’s life cycle. Uncover the lives that our clothes led before they got to the store and discover your voting power as a consumer towards a fairer, healthier and more sustainable planet. |
| Read: “Product History.”  http://biopvc.com/history.html  Related article: “PVC Recycling in Europe.”  http://www.pvc.org/en/p/recycling-in-europe | polymers | How are bioplastics better than regular plastics? Are they biodegradable? Can they be recycled?(10) |
| Read: “Financial News Release.”  <http://ir.huntsman.com/phoenix.zhtml?c=186725&p=irol-newsArticle&ID=843280&highlight=> | green chemistry in industry | The chemical company Huntsman forms a Green Chemistry Strategic Business Unit with applications including agriculture, cleaning agents, paints, and foams. (11) |
| Read: “ Biomimicry: How Copying Nature LEads to Healthier Humans, Planet.” <http://www.huffingtonpost.com/2012/01/04/biomimicry-science-copies-nature_n_1184667.html> | innovations,biomimicry | Biomimicry is the process of designing products that imitate phenomena found in nature. Mussles are can help us design water proof adhesives. (12) |
| Watch and read: “ Brent Constantz Builds Cement Like Corals Do.” <http://earthsky.org/human-world/brent-constantz-builds-cement-like-coral-do> | biomimicry, chemical reactions | Corals inspire how to make concrete. and power plant emissions are used to make the calcium carbonate for concrete. (13) |
| Read: “Environment” and all the subheadings under the “Environment” tab.  <http://www.greencellfoam.com/>  Read: “Mushroom Materials.”  http://mushroompackaging.com/ | innovations, polymers | Starch based foams for coolers and packing materials could replace the traditional use of styrofoam. Materials can be grown rather than manufactured.(14) |
| Read: “Green Chemistry Challenge Winners: Yi Tang and Codexis.”  [http://www.epa.gov/greenchemistry/pubs/pgcc/winners/gspa12.htm](http://www.epa.gov/greenchemistry/pubs/pgcc/winners/gspa12.html) | organic chemistry, catalysis | A safer and more efficient process is created for making a drug that lowers cholesterol. (15) |
| Read: “Buckman WIns Green Chemistry Challenge Award.”  <http://www.buckman.com/about-us/news/562-buckman-wins-presidential-green-chemistry-challenge-award> | consumer products, catalysis | Stronger paper can be made using a green process involving enzymes derived from renewable resources. (16) |
| Read: “Green Chemistry Innovation Case: Nike.”  [http://www.oeconline.org/our-work/economy/green-chemistry/green-chemistry-innovation-resource-hub/why-benefits-of-using-green-chemistry/green-chemistry-innovation-case-studies/green-chemistry-innovation-case-study-nike](http://www.google.com/url?q=http%3A%2F%2Fwww.oeconline.org%2Four-work%2Feconomy%2Fgreen-chemistry%2Fgreen-chemistry-innovation-resource-hub%2Fwhy-benefits-of-using-green-chemistry%2Fgreen-chemistry-innovation-case-studies%2Fgreen-chemistry-innovation-case-study-nike&sa=D&sntz=1&usg=AFQjCNH6liLDsNZQtE2QYV5UE272lIB2Kg) | innovations, polymers | Nike collaborated with their supply chain partners to reduce toxicity during the manufacture of rubber for athletic shoes by using vegetable oils and benign accelerators. (17) |
| Watch: **Three Meals that Matter**  [**http://greennovate.org/three-meals-that-matter**](http://www.google.com/url?q=http%3A%2F%2Fgreennovate.org%2Fthree-meals-that-matter&sa=D&sntz=1&usg=AFQjCNEp9dSyWkwVoWQx3-6bnkwLQ7Um3w) | sustainability  environmental science | This video takes a closer look at our food and where it comes from. For those of us lucky enough to get 3 meals a day, we’ll eat about 100,000 meals in each of our lifetimes. That makes our choice of what to eat one of the most impactful decisions we can make! Find out how 3 meals a day can sustain not only our bodies, but also our planet and society. |
| Watch: **Journey of Sustainable Business**  [http://greennovate.org/the-journey-of-sustainable-business](http://www.google.com/url?q=http%3A%2F%2Fgreennovate.org%2Fthe-journey-of-sustainable-business&sa=D&sntz=1&usg=AFQjCNEMQ9C31nAPItiyLuvNHIbZ8Tzcaw) | sustainability  environmental science | What is a sustainable business? Is it a fancy buzzword? A passing trend? Or a real commitment to making zero impact on the local and global environment, community and economy? Is making profit questionable or the manner in which we do so? Find out what it takes to embark on the road to a sustainable business. |
| Watch: **Responsibility Calling**  <http://greennovate.org/responsibility-calling> | sustainability  environmental science | We all love having the latest gadgets, but how should we respond when we hear about mistreatment of workers or toxic e-waste? |

**Green Chemistry Assignment**

**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Date \_\_\_\_\_\_\_ Block \_\_\_\_\_**

**Name of Article or Video**

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**3, 2, 1 Summary**

Write a paragraph about

3 things you learned

2 things you found surprising

1 question you have

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**Additional Notes for Teachers**

1. “Graphene is an allotrope of Carbon and is described as a one-atom thick layer of graphite. Graphene kills bacteria by, ‘slicing through their membranes and yanking out their phospholipids.’ The hope is this could be used as a green antimicrobial material for everyday use, such as in a Band-Aid. Advantages include less bacterial resistance due to the mechanism it uses and it has been shown to work well on E-coli bacteria. Concerns with using graphene include its effectiveness on other types of bacteria and the worry that it could be toxic to healthy, non-bacterial cells. Ultimately, more research needs to be done, but there is promise of graphene being a green antimicrobial agent.” Reviewed by Erika Fatura

2. “L'Oreal, several years past, developed Pro-Xylane, which is extracted from the beech wood plant using Green Chemistry methods. This naturally-derived molecule is extracted using a water solution, making it non-toxic, biodegradable, and bio-assimilable, meaning it can be reabsorbed into the environment without causing any harm. The result is a molecule that works with skin’s natural chemistry and with the environment. By switching to this new formulation 100 tonnes of waste was prevented from being released per an unstated period of time. The use of chemicals and elements such as lead found in make-up is very concerning to me as a female who wears make-up. Many girls discount the minimal amount of make-up that is used on a daily basis and negate the toxicity levels that can build from daily wear from leaching into the skin. It's nice to know at least one make-up producer is making an effort to use green chemistry principles.” Reviewed by Melisa Jennings

3. “This is a technology which is not fully developed yet, but is quite interesting. Scientists are working on the development of microcapsules containing bacteria which will secrete limestone when wet. The idea is that when these microcapsules are mixed into concrete, if the concrete cracks, water would enter the crack and cause the bacteria to produce limestone to fill in the crack. By allowing for less repair of concrete and a longer concrete lifespan, they could significantly reduce CO2 emissions from the concrete industry (which now accounts for over 7% of the CO2 emissions globally).” Reviewed by Diane Duke

4. “As a biology teacher, I searched for an example of a green chemistry inspired technology that I could use in class. I found a few articles about MIT Media Lab and their researcher with 3-d printing. They are studying silk worms, specifically how different conditions affect the patterns and density of the silk. The “3-d printer” contained 6,500 silkworms. Altering light and heat conditions the silkworms produced a silk print or “dome” that is currently MIT Media Lab lobby. The mere idea of using a living organism in this way would be fuel for a great bioethics discussion in class. There is a cool video of the process used to construct the dome or pavilion- see the second or 3rd url.” Reviewed by Melissa Rice

5. “Mater-Bi is produced by Novamont, an Italian research company dedicated to environmental alternatives to polyethylene-based plastics. Mater-Bi is the first completely biodegradable and compostable bio-polymer ever invented. The processes are protected by more than 200 groups of patents. All of the Mater-Bi™ grades: are completely biodegradable and compostable; can be worked using the same processes as for traditional plastics and with similar output; can be printed on, using normal inks and printing techniques, without the need for crown treatment; can be colored in bulk, using biodegradable Master-batches; are intrinsically anti-static; can be sterilized using gamma rays. I feel its important to show our students there are other solutions out there for products that already exist. With our technology class we found alternatives to using plastic bags for daily use, but here a real solution to the composting/degradation issues.” Reviewed by Allison Nofzinger

6. “Green chemistry is being used to clean water! I find this very exciting and hopeful as clean drinking water is so scarce in many parts of the world (due largely to industry not following green chemistry principles). Professor Terry Collins, Carnegie Mellon, talks about this being a solution to a real problem and I can't think of many better ways to apply chemistry. In brief, this is being done using hydrogen peroxide and a catalyst at room temperature. I looked a little more and found that this is being used in municipal water treatment already and can help with odor/taste and the removal of many chemicals including hydrogen sulfide and iron.” Reviewed by Sarah Mitch

7. “Producing packaging is one the largest industries that has been trying to adopt more sustainable technologies. Last year I did a very brief introduction to packaging, waste, and the chemistry behind all the industries whether it be pharmaceutical, food, make up andit hits so close to home for all my studetns as consumers. What is the stuff all of or stuff comes in? That's the question I give my students. All of that leads to PACKAGING!! There is a variety of technology out there that this one company is using like recycled plastics but I found one very interesting. It is made in part with from sugar cane, so companies that need clear plastic packaging can replace fossil fuel-based material with up too 30% plant based material. Diving into the world of plastics has given me lots of ideas of projects and research for my students!!” Reviewed by JB Kavaliauskas

8. “This is a third world Green Technology innovation that is a solution to a third world problem. Each of these Solar Bottle Lights provides 55 watts of free and clean light. I used this as an activator for my Chemistry classes this year and the students were completely absorbed by it. I think they were a bit taken back by the fact that people that had so little could be so positively affected in so many ways by such a simple Green Innovation.” Reviewed by Anthony Fimognari

9. “Traditional wood finishes have consisted of a mixture of solids and solvents, with hardening of the solids on the surface as the solvent evaporates. The finish of choice in the 18th and 19th centuries was shellac--insect shells dissolved in alcohol. Shellac is nontoxic and easy to apply, but has very poor resistance to water and alcohol. Varnish (resins dissolved in oils like mineral spirits) became popular in the late 19th and early 20th century, but was superseded by lacquer (1928-cellulose dissolved in volatile solvents such as acetone) for high quality finishes. Lacquer, as opposed to varnish, is easy to spray. The development of finishes since--for wood and also other applications such as automobiles, has largely continued to be that of solids in "VOC's," or volatile organic compounds. Volatile organic compounds are used because they, as their name says, evaporate easily, leaving behind the solids. The development of water based, non-toxic paints and finishes that rival the quality of their toxic counterparts has been a challenge for years. The polarity of water makes even flow of the paint/finish uneven, and the attraction between particles results in longer drying times. The development of Sefose, the trade name for a polymer of sucrose and fatty acids, by Proctor and Gamble, may be a step forward in the development of a nontoxic finishes for wood, corrosion protection for metals, and for lubricating coatings. Sefose is made by a catalyzed reaction between sugar and a vegetable oil, such as soybean oil, in a solventless nontoxic process. Ester bonds form from the reactions between the O-H groups on the sucrose and the acid groups of the fatty acids. The resulting molecule has sucrose at its center, with the attached fatty acids coming off of the sugar like spokes. Two of the Sefose finishing products have the trade names Chempol MPS 4426 and Chempol MPS 2410. The Chempol 4426 is 100% solids. Chempol 4426 thus has no solvent, let alone a volatile organic solvent (I am puzzled by how it solidifies on exposure to air). Chempol MPS 2410 has water for a solvent (45%). The Chempol MPS 4426 is useful for protecting wood and metal, whereas the the MPS 2460 seems to be more suited for just wood (unclear, and quite frustrating!). Whether or not Sefose for solids in paints and other coatings takes hold remains to be seen. Sefose appears to be cost competitive, and is completely nontoxic in production, application, and is biodegradeable. It does provide reasonably good chemical resistance except for a reaction with bases (5% sodium hydroxide destroys it). Sefose becomes slightly discolored in the presence of 409, but some house paints (like that on mine!) do the same. Past tolerance for toxic processes in making and applying coatings has set high standards for durability and appearance, but Sefose based coatings may be able to compete. Proctor and Gamble won the 2009 Presidential Green Chemistry Award in the designing greener chemicals category for its development of Sefose.” Reviewed by Pat McFarland

10. “While on a recent family vacation I happened to notice that my room key card was made of bioPVC a product I had never heard of before. This sounded great a biodegradable thermoplastic. According to the website ( http://biopvc.com/product.html ) additives are introduced to the traditional PVC resin to make the material biodegradable under compost conditions. However, there is no data to indicate the material converts as claimed to CO2 and H2O. Also, there is no indication of what happens to the chloride ions present in the PVC. Further web based research found this article in which the claims of bioPVC are questioned and suggestions are made for testing reliable claims. http://www.bpiworld.org/resources/Documents/Narayan%20Bioplastics%20Article%202009.pdf

While this is not the intent of the topic I found this to be very interesting and educating because without the research I would have thought what a great product. The chemist in me was curious how safely recycling halogenated plastic in compost/landfills was possible so I kept looking. What I was able to come up with was there does not seem to be a product that has empirically proven that it can do this. PVC can be recycled traditionally by original use as can be found here in information about recycling PVC in Europe. <http://www.pvc.org/en/p/recycling-in-europe> This material seems to be a great one to use to get students to better evaluate the claims of a manufacture of an Eco-friendly material and create better consumers.” Reviewed by Erik Swanson

11. “After reading the articles I was interested to see what my former employer Huntsman has been doing in light of the Green Chemistry movement. When I worked for the company 14 years ago talk of green chemistry was not part of our everyday language or even on the horizon. I was happy to see that Huntsman a $13 billion dollar chemical company, formed a Green Chemistry Strategic Business Unit in 2006. They are looking into using carbonates as solvents in agricultural and industrial cleaning agents as well as non volatile components in paints and insulated foams. Huntsman is also committed to energy efficiency and conservation.”

Reviewed by Alyssa Vachon

12. “Biomimicry is the process of designing products that imitate phenomena found in nature. These processes typically go hand in hand with green chemistry principles. Professor Kaichang Li of Oregon State University is developing an adhesive inspired by blue mussels. On a trip to the Oregon coast he observed blue mussels sticking to slippery wet rocks no matter how turbulent the tide was. He was so curious that he took some mussels back to his lab and studied the material they produced that allowed them to stick so effectively. From these studies Professor Li developed a recipe for a soy-based, water proof adhesive. This new adhesive can replace formaldehyde-based adhesives that are traditionally used for wood cabinets and furniture. This benefits the health of the environment and people by greatly reducing the toxicity in making the adhesives and in the adhesives themselves.” Reviewed by Marianne McChesney

13. “This is another concrete related process. Emissions from a power plant are passed through seawater to form more carbonate ions. Calcium carbonate precipitates out and is used to make a concrete that stores carbon dioxide. This is being tested at a fairly large scale in Northern California.” Reviewed by Ann Akey

14. “Starch based foams have started to gain traction in many areas. This company is using them to make coolers and other packing materials: http://www.greencellfoam.com/ I have heard some controversy over the source of the starch, but this is certainly more environmentally friendly when disposed of after use. More recently, some companies like this one: http://mushroompackaging.com/ are growing custom packing materials rather than manufacture them in any traditional sense of the word.” Reviewed by Carolyn Scerra

15. “Professor Yi Tang of UCLA and Codexis, Inc. developed a significantly safer and more efficient process to make Simvastatin, a drug taken to lower cholesterol. The key part of the synthesis is that the biocatalyst LovD transfers an acyl group from the donor molecule, DMB-SMMP, in just a single step, thereby reducing waste (principles #1 & #2), toxicity (principle #3), and steps (principle #8), while still meeting the needs of the consumers (principle #4).” Reviewed by Marianne McChesney

16. “The Buckman company created the Maximyze technology for producing paper and paperboard that increases paper strength (principle #4). The traditional process of adding pulp and using chemical fiber treatments is replaced by fermentation processes that use combinations of enzymes derived from renewable resources (principle #9), consequently reducing the amount of energy (principle #6) and chemical additives (principles #5 & #8).” Reviewed by Marianne McChesney

17. “Nike collaborated with their supply chain partners to reduce toxicity during the manufacture of rubber for athletic shoes. The methods and chemicals used in processing the rubber were modified to use benign accelerators (principle #9) and vegetable oils (principles #7& #10) while maintaining the high level of performance consumers expect from Nike products (principle #4).” Reviewed by Marianne McChesney