 **Fabulous Fabrics**

**MIDDLE SCHOOL**

**Green Chemistry**

**Background:** Fabrics are an incredibly diverse group of materials. From high-tech athletic clothing to elegant formal wear, the purpose a fabric serves often is determined by its properties. Most textile products are made using a combination of natural and synthetic fibers. When considering fabrics from a green chemistry perspective, it is difficult to determine whether one fabric is “greener” than another because of the many components that must be considered in the production of fabrics. Synthetic fibers mostly come from non-renewable resources, but some of these can be recycled. Natural fibers must be grown or produced, which often involves land, water, and pesticide use. The dye process is also a challenge in relation to green chemistry, as dyeing usually produces a great deal of water waste and often uses hazardous materials. Because textiles are such an important part of our world, there is a great opportunity for future scientists and engineers to help create greener, more sustainable materials for all of our diverse fabric needs. Some companies, like Steelcase, Inc., are making strides toward safer fabric chemistry. For more information on Steelcase’s safer fabric chemistry, visit <http://www.c2c-centre.com/product/interior-design-furniture/cogent%E2%84%A2-group>.

*pH and Fabric Type*

In this lab we’ll focus on two major types of dyes: acid dyes and basic dyes. Acid dyes will dissolve in water and gain a negative charge, while basic dyes will dissolve in water and gain a positive charge. Different types of fabrics will take better to either acidic or basic dyes, depending on the properties of the individual fabric. As a reminder, opposite charges attract, so a positively charged dye will bind to a negatively charged fiber. This lab considers two main categories of fibers: synthetic and natural. In general, synthetic fibers will typically have a slight negative charge and will therefore better absorb a basic dye. Natural fibers can come from either animal or plant sources. Textiles that come from animal sources, like silk and wool, are usually made up of proteins that have a slight positive charge, so they will better absorb acidic dyes. In contrast, natural fibers made from plants, like cotton, have very different properties than other types of natural fibers and will dye best with dyes other than acidic or basic dyes, like direct dyes or vat dyes. Students will consider the difference between natural and synthetic fibers and investigate the ways that a variety of fabrics will interact with both basic and acidic dyes.

**Additional Resources:**

Mondal, Md. Ibrahim H., and Md. Khademul Islam. "Effect of pH on the Dye Absorption of Jute Fibre Dyed with Direct Dyes." *Oriental Journal of Chemistry*. Oriental Journal of Chemistry, 31 Dec. 2014. Web. 06 Mar. 2017.

Reddy, Avanija, Don F. Norris, Momeni S. Momeni, Belinda Waldo, and John D. Ruby. "The pH of beverages in the United States." *Home - American Dental Association*. JADA.ADA, 2016. Web. 20 Mar. 2017.

Baig, Gulzar A. "Effect of pH on the Coloration of Synthetic Fibers with Indigo Blue." *College of Textile Engineering and Technology*. Indian Journal of Fiber and Textile Research, Sept. 2012. Web. 6 Mar. 2017. <<http://nopr.niscair.res.in/bitstream/123456789/14697/1/IJFTR%2037(3)%20265-272.pdf>>.

"Factors That Affect Dye Binding - LabCE.com, Laboratory Continuing Education." *Factors That Affect Dye Binding - LabCE.com, Laboratory Continuing Education*. MediaLab, n.d. Web. 06 Mar. 2017.

*Acid Dyes|Properties of Acid Dyes|Mechanism of Dyeing with Acid Dyes* <http://textilelearner.blogspot.com/2012/01/acid-dyes-properties-of-acid-dyes_21.html>

*Basic Dye/Cationic Dye|Properties of Basic Dyes|Dyeing of Acrylic with Basic Dyes* <http://textilelearner.blogspot.com/2011/03/defination-properties-working-procedure_7918.html>

**Objectives:** Students will….

* Understand that synthetic fabrics come from natural resources and impact society
* Apply the green chemistry concepts to decision making
* Consider properties of natural and synthetic fabrics
* Investigate the impact of pH changes through dyeing

**Key terms:** Acids, bases, pH, natural, synthetic

**Materials:**

* Multi-fiber ribbon from Educational Innovations (2 strips per pair, from: <https://www.teachersource.com/product/fabric-id-kit-sm-6d/chemistry>)
* Microscopes (or magnifying glasses)
* Digital scale
* Safety glasses
* Red Kool-Aid® for dye
* Plastic cups (2 per pair)
* Plastic pipette (2 per pair)
* 50-mL beaker (1 per pair)
* 100-mL beaker (1 per pair)
* Ammonia (30 mL per pair)
* Vinegar (<30 ml total)
* Red and blue litmus strips (6 of each color per pair)
* Stirring rod/spoon
* Permanent markers (1 per pair)
* Paper towels

**Time Required:** Two 45-minute class periods

**Standards Met:**

**MS-PS1-3.** Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

**MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

**Keys to Success:**

* Examples of common natural and synthetic fibers are listed in the table below:



|  |  |
| --- | --- |
| **Synthetic** | **Natural** |
| Polyester, rayon, spandex, nylon, acrylic | Wool, silk, linen, cotton, cashmere |

* Magnifying glasses may be used in place of microscopes. If neither is available, a visual assessment may be made without magnification.
* Students will be given two multi-fiber ribbons at the beginning of their experiment and immediately begin dyeing one of these strips. This will allow sufficient time for the fabric to dye without creating any down time in class.
* Looking at the multi-fiber ribbon and the fabrics key, the black line on the multi-fiber ribbon indicates the top of the strip.
* Kool-Aid is used in this experiment not only because it is safe for students, but also because it is used as a standard stain in a range of products, from industry to fabric cleaning products.
* If necessary, remind students that any food materials used in the lab for experiments are not for eating or drinking.

**Teacher Preparation:**

* Teachers may wish to have pre-dyed samples on hand as a reference.
* If microscopes are available, set them up before class.
* To save time during the experiment, you may wish to pre-measure cups of Kool-Aid and small cups or bottles of ammonia for each student pair.
* Set aside a cup each of Kool-Aid, vinegar, and ammonia for the *Explain* class demo.

**Procedure:**

5 E Procedure:

*Engage:*Students discuss the difference between natural and synthetic fabrics by considering the different fabrics students are wearing.

* Ask students if they know what fabric the shirt they are wearing is made from. Have them work with a partner to read the tag and tell you so you can write the fabric names on the board. Create two unlabeled columns: one column should include natural fibers, while the other should include synthetic fibers.
* Ask students if they know of other fabrics that are not listed, then add them to the board.
* Explain that you have purposely separated the fabrics into two categories. Instruct students to break into pairs to discuss what the two categories might be. After a minute or two, ask students to share their ideas. Label the columns “Natural” and “Synthetic.”
* Review with students the difference between natural and synthetic materials. Natural materials are derived from nature while synthetic materials are man-made.

*Explore:*Students make predictions about the ability of different fabrics to absorb dye.

* Pass out the Fabulous Fabrics Lab: Student Lab Report and instruct student pairs to brainstorm ways to tell different fabrics apart. Have students capture their ideas in their Lab Report.
* Give each pair two multi-fiber ribbons and paper towels. If microscopes are unavailable, pass out magnifying glasses.
* If you have pre-measured the cups of Kool-Aid, pass out two cups of dye to each group. Instruct students to start dyeing *one* of their fabric strips and mark the time. Students will remove this strip in 10 minutes. The other fabric strip will use to make their predictions.

*Explain:*Students consider the difference between acids and bases, as related to their dye.

* Explain to the class that there are two common types of dyes used to dye fabrics: acid dyes and basic dyes. The dye they are using is either acidic or basic, so the strip they are currently dyeing will tell them how well each of their fabrics dyes in that type of dye. However, they need to evaluate their fabric in both basic and acidic dyes.
* Ask the class to reflect on what they know about acids and bases.
* Ask the class to predict whether their Kool-Aid dye is acidic or basic.
* Review the function of litmus paper with the class.
* Pull out the cups of Kool-Aid, vinegar, and ammonia. Invite one volunteer to help determine whether the Kool-Aid is acidic or basic using litmus paper.
* After determining that Kool-Aid is acidic, tell the class that they will need to add either vinegar or ammonia to their solution to change it from acidic to basic. Ask the class to predict which one they will need to add.
* Invite another volunteer to perform a litmus paper test to determine whether vinegar or ammonia is basic.
* After determining that ammonia is basic, pass out cups of ammonia and instruct student pairs to add ammonia to their second cup of dye in 5-mL increments until their dye changes from acidic to basic. Students will use litmus paper to determine when this change occurs. (step #11 on student lab report)
* Once their dye is basic, students should add their second fabric strip to this cup and record the time.
* Instruct students to predict the dyeability of each fabric in the multi-fiber ribbon according to the directions on their Lab Report.
* Once the first strip has been in the dye for 10 minutes, have pairs remove their first fabric strip from the acid dye.

*Elaborate:*

* Instruct students to fill out predictions for their basic-dyed fabric strip in the data table while their second strip is dyeing.
* Have students compare the dyed results of their first fabric strips to their predictions by filling in their data table.
* After 10 minutes have elapsed for the second fabric strip, have students remove it from the basic dye.
* Instruct students to finish filling in their data table and to complete the Discussion and Conclusion sections of their Lab Report.

*Evaluate:*

* Ask student pairs to share their answers to the Discussion and Conclusion questions:
* How did pH affect the dyeability of each of the fabrics? What patterns, if any, did you notice?
* Looking at your results, what was surprising?
* Which fabrics dyed best in the acidic dye? In the basic dye?
* Considering the type of materials and the dyeability of the fabrics, which fabric do you believe a green chemist would choose? Justify your answer.
* Collect Student Lab Reports for evaluation.

**Extension Option:**

* Use multiple colors of Kool-Aid (or other drink mix/food dye) and compare how each dye works for each fabric.
* For more guided inquiry, students can be given an unknown sample of one type of fabric from the multi-fiber ribbon and challenged to identify it using the dyeing process.
* If incorporating this lesson into the biodegradable cell phone case unit, you may wish to encourage students to use fabric to enhance the design of their case. Some ideas are listed below:
  + They can use the 6 strips dyed in class to decorate cell phone cases.
  + You can provide fabric or ask students to bring in fabric & dye it in class.
  + You can assign this as part of homework.
    - Example: Gather materials that you would like to use to make your phone case aesthetically pleasing (fabric, old t-shirt to cut up, etc.). Bring them to school.

**Fabulous Fabrics: Student Handout**

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

**Fabulous Fabrics: Student Lab Report**



**Materials:**

* 2 multi-fiber ribbon strips
* Microscope or magnifying glass
* 2 plastic cups
* Kool-Aid powder
* Digital scale
* 100-mL beaker for water
* 50-mL beaker
* 6 strips each of red and blue litmus paper
* 2 Plastic pipettes
* Safety glasses
* Stirring rod/spoon
* Permanent marker
* Paper towels
* 30 ml Ammonia or vinegar (from teacher)

**Predictions:**

With a partner, brainstorm the ways you can tell fabrics apart.

**Procedure:**

1. Take turns using the microscope or magnifying glass to analyze the multi-fiber ribbon.
2. Refer back to your brainstormed list of how to tell fabrics apart and make any changes or additions you now have.
3. Put on your safety glasses.
4. Label your two cups “1” and “2” with a permanent marker.
5. Use the digital scale to weigh 0.7 grams of Kool-Aid (dye) into each cup.
6. Use the 100-mL beaker to measure 50 mL of water; pour it into Cup 1 and stir with a stirring rod or spoon.
7. Measure 30 mL of water, pour it into Cup 2, and stir.
8. Pause for class discussion.
9. Fill out the data table with your predictions for the acidic-dyed fabrics and the basic-dyed fabrics, using the star rating system (explained above the data table).
10. Submerge one fabric strip into Cup 1, then set timer for 10 minutes.
11. Obtain either ammonia or vinegar from your teacher (based on the class consensus) in your 50-mL beaker and begin adding it in 5-mL increments using pipette (approximately 5 full pipettes) to Cup 2. Use your litmus paper to test when you have added enough to change your solution’s pH.
12. Submerge your second fabric strip into Cup 2 and start a timer.
13. After 10 minutes, remove your first strip from Cup 1 and place it on a paper towel.
14. Examine your first fabric strip and fill out your data table with your observations.
15. After 10 minutes, remove your second strip from Cup 2, place it on a paper towel, and complete your data table with your observations.

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| --- | --- | --- | --- | --- | --- |
| **Name of fabric** | **Natural or synthetic?** | **Prediction: acid dye rating** | **Actual: acid dye rating** | **Prediction: basic dye rating** | **Actual: basic dye rating** |
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Fill in the table using the star scale below to predict how well each fabric will dye. When you look at the multi-fiber ribbon key, the black line on the fabric strip corresponds with the top of the key.

✰ = will not dye well

✰✰ = will dye lightly

✰✰✰ = will dye moderately

✰✰✰✰ = will dye well

✰✰✰✰✰ = will dye excellently, with vibrant, dark color

**Discussion:**

1. How did pH affect the dyeability of each of the fabrics? What patterns, if any, did you notice?
2. Looking at your results, what was surprising?

**Conclusion:**

1. Which fabrics dyed best in the acidic dye? In the basic dye?
2. Considering the type of materials and the dyeability of the fabrics, which fabric do you believe a green chemist would choose? Justify your answer.

**Teacher Key for Fabric Strips Dyeing Patterns**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name of Fabric** | **Type of Fiber** | **Acid Dye**  **(negatively charged)** | **Basic Dye**  **(positively charged)** |
| Filament acetate  (polar, not charged) | synthetic | low to no absorption | low absorption |
| Bleached cotton  (polar, not charged, but because there are the OH groups, it absorbs dye--acetal groups have methyl group, which is not as “sticky”) | natural (plant-based) | moderate to high absorption | high to very high absorption |
| Spun polyamide  (polar, not charged) | synthetic | high absorption | low to no absorption |
| Spun polyester  (polar, not charged) | synthetic | low to no absorption | low absorption |
| Spun polyacrylic | synthetic | low to no absorption | low absorption |
| Spun silk  (protein, positively charged groups) | natural (animal-derived) | very high absorption | low absorption, color is washed out/muted |
| Spun viscose  (negatively charged: modified cellulose with carbon disulfide groups) | natural (plant-based) | low to moderate absorption | high absorption |
| Worsted wool  (protein, positively charged groups) | natural (animal-derived) | very high absorption | moderate absorption, color is washed out/muted |

Patterns to notice:

* Synthetic fibers will dye better with basic dye, with the exception of spun polyamide (nylon). This is because nylon’s structure has a slight positive charge, unlike the typical synthetic fibers, which are slightly negative.
* Animal-derived natural fibers will dye better with acid dyes.
* Plant-based fibers are harder to predict, as they are typically dyed with neither acid nor basic dyes.