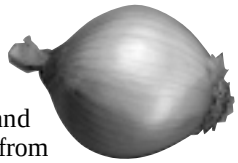
Colors to Dye for: Preparation of Natural Dyes

by the *Journal*'s Editorial Staff



Background

Use of dyes can be traced to earliest history. The coloring properties of materials such as berries and bark were most likely discovered when clothing accidentally became stained with them. Dyes made from natural sources such as plants, animals, and minerals tend to produce colors that wash out easily. With most natural dyes, a mordant can be used to make the color more permanent. In the mordanting process the fiber is treated with a solution of a metal salt (usually an aluminum, chromium, copper, iron, or tin salt). Then the fiber is dyed. Metal ions from the salt form strong bonds with the fiber and also with the dye, thereby holding the dye to the fiber (*1*).

Integrating the Activity into Your Curriculum

Preparation and use of dyes is a practical application of chemistry. Dyed fabric is common in daily life. An investigation of natural dyes leads to interesting historical anecdotes that connect chemistry to the past. A recent issue of *JCE* includes the history of "royal purple" and "biblical blue" dyes (*2*). A study of the structures of dye molecules can be easily integrated into a discussion of organic chemistry and functional groups. Absorption of visible light of chromophores can be used as examples in a lesson on spectroscopy. Some natural dyes are acid–base indicators and can be incorporated into a section on acid–base chemistry. Discussion of mordants can be included in an introduction to metal complexes, because mordanting involves complexation of metal ions by dye and fiber.

About the Activity

This activity can be done in the chemistry laboratory or as a take-home project in a kitchen. Small cooking pots or other containers that can be heated on a stove or in a microwave oven can be substituted for laboratory equipment.

Caution: Students should not eat or taste food or other items in the laboratory, or anything that has been in contact with laboratory equipment.

The idea for this activity was suggested by a more complex experiment in *Chemistry: The Experience* by Ann Ratcliffe (*3*). Many other published chemistry activities and demonstrations involving dyes are available. Two examples are listed here (*4*, *5*).

Students should observe that dye is retained better by cloth that has been soaked in the boiling mordant solution. Adding acid or base will change the color of the cloth dyed with blueberries but has no effect on cloth dyed with onion skin. [A previously published *JCE* Classroom Activity describes the extraction of anthocyanins from flowers for use as an acid–base indicator (*6*).] The color change may not persist when the cloth is rinsed or after it dries. Colors will be less bright after the cloth dries. Students may conclude that onion-skin dye is a more suitable dye for clothing.

The materials needed should be easy to obtain. Alum and cream of tartar can be found on the spice shelf at the grocery store. Your school cafeteria or a local restaurant may be able to provide yellow onion skins, and grocery stores often have many loose skins at the bottom of the onion bins. Fresh, frozen, or canned blueberries (but not blueberry pie filling) can be used. If blueberries are not available, red cabbage can be substituted, but cloth must be left in the dye solution significantly longer to achieve a similar color. Any white cotton cloth can be used. Remnants from a fabric store are an inexpensive option, but old T-shirts, flour sacks, and dish towels also work well. For best results, new cloth should be laundered before it is dyed.

Natural dyes can be obtained from many sources, such as herbs, fruits, and vegetables; for example, try red onion skin, tea, and turmeric. Students may enjoy tie-dyeing a T-shirt with a natural dye. Internet sites that give tie-dye instructions are provided on the Student Side of this Classroom Activity. These instructions use commercial dyes, but natural dye and a mordant can be substituted.

Answers to Questions

1. A mordant is used to make the fabric colorfast. The color does not come off as easily when the fabric is washed.
2. Blueberries can be used as an acid–base indicator. The dye will probably be purplish and its color will vary (pink, purple, green) with pH. The color tends to fade quickly. It is not a good choice if constant, long-lasting color is desired.

Additional Activities and Demonstrations

1. Séquin-Frey, M. *J. Chem. Educ.* 1981, *58*, 301–305.
2. Gettys, N. S. *J. Chem. Educ.* 1999, *76*, 737–746.
3. Ratcliffe, A. *Chemistry: The Experience*; Wiley: New York, 1993; pp 197–204.
4. Borgford, C. L.; Summerlin, L. R.; Ealy, J. B. *Chemical Demonstrations, A Sourcebook for Teachers*, Vol. 2, 2nd ed.; American Chemical Society: Washington, DC, 1988; pp 193–194.
5. Borgford, C. L.; Summerlin, L. R. *Chemical Activities, Teacher Edition*; American Chemical Society: Washington, DC, 1988; pp 84–86.
6. Anthocyanins: A Colorful Class of Compounds *J. Chem. Educ.* 1997, *74*, 1176A–1176B.

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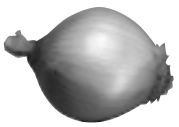
What color clothing do you like to wear? Thanks to inexpensive synthetic dyes, people can have clothing of just about any color they want. Dyes available for most types of fabrics can produce brilliant colors that resist fading. Before the middle of the 19th century, however, the only dyes available came from natural sources such as plants, animals, and minerals. The colors usually were not very bright and tended to wash out with water. Some colors, such as blue and purple, were extremely difficult to produce. As a result, these colors of cloth were so expensive that only royalty tended to wear them. You can easily extract colored compounds such as those shown below from plant material, use them to dye white cloth, and investigate ways to change the color and prevent it from washing out.



*Q**uercetin*** is the compound that makes yellow onions yellow.

Anthocyanins make blueberries blue. They have the generic structure shown, differing only in the groups R and R´.

Try This

You will need: four 100-mL beakers, water, spatula, alum, cream of tartar, Bunsen burner or hot-plate, tongs, at least four small (1–2 in.) squares of white cotton cloth, yellow onion skins, blueberries, spoon, paper towels, vinegar, baking soda, and a dropper. In each step, record your observations paying special attention to colors.

Caution: Do not eat or taste food or other items in the laboratory, or anything that has been in contact with laboratory equipment.

__1. Pour 50 mL of water into a 100-mL beaker (beaker 1). Add a pea-sized scoop of alum and about half that amount of cream of tartar and stir. Bring the solution to a boil over a Bunsen burner or on a hot-plate. Add two small squares of white cotton cloth and boil for two minutes. Set the beaker aside. The squares will be used in steps 4 and 6.

__2. Tear the outer, papery skin from a yellow onion into pieces no more than 1 inch square. Place enough pieces in a 100-mL beaker (beaker 2) to cover its bottom with 2 or 3 layers of onion skin. Add 50 mL of water to the beaker. Bring the solution to a boil over a Bunsen burner or on a hot plate. Continue to boil for five minutes.

__3. Wet a new square of cloth with water. Place it in beaker 2 so it is completely submerged and boil for 1 minute. Using tongs, remove the cloth and rinse it with water. Place the cloth square in the appropriate area on a labeled paper towel.

__4. Use tongs to remove one of the cloth squares from beaker 1. Repeat step 3 using this square. Compare to the dyed cloth square from step 3.

__5. Pour 50 mL of water into a 100-mL beaker (beaker 3). Add 4–5 blueberries to the beaker and mash them with a spoon. Bring the solution to a boil over a Bunsen burner or on a hot-plate. Continue to boil for five minutes.

__6. Repeat steps 3 and 4 substituting the blueberry mixture in beaker 3 for the onion skin mixture in beaker 2.

__7. Mix a small scoop of baking soda with a few milliliters of water in a clean beaker (beaker 4). With a dropper, place 1–2 drops of the baking soda solution on one corner of each cloth square. What happens? Rinse the dropper thoroughly, then place 1–2 drops of vinegar on the opposite corner of each square. What happens? Rinse the fabric squares under cool running water. Is there a change? Allow the squares to dry overnight. Is there any change after the cloth dries?

Optional: Try variations in the procedure above such as changing the amount of dye source, the length of time the cloth spends in the dye solution, and the temperature of the dye solution. With your instructor's approval, test other fruits, vegetables, flowers, herbs, etc. to see if they can be used as natural dyes. How many different colored dyes can you find? Tie-dye a larger piece of cloth or a T-shirt using natural dyes. The last two Web sites listed below give tie-dye instructions that use commercial dyes, but you can adapt them for use with natural dyes.

Questions

__1. The solution prepared in step 1 is called a *mordant*. Based on your observations, what is the purpose of a mordant?

__2. What else might blueberries be used for in chemistry lab? Is the dye they produce really blue? Why might some people not want to wear clothes dyed with blueberries?

Information from the World Wide Web *(accessed October 1999)*

Dyes. *http://cator.hsc.edu/~kmd/caveman/projects/dye/*
Dyes and Colors. *http://www.dyesonline.com/intro.htm*
Tie-Dye a T-shirt. *http://www.sos.state.mi.us/history/museum/kidstuff/sixties/tiedie.html*
Folding Directions. *http://www.prochemical.com/tdfold.htm*