Effect of pH on Plant-Derived Dyes

by Regina Sievert

Grade level 9-12
(adaptable to middle school)

Time required
One 50-minute period

Materials/Technology
(per group)
Goggles for each student
1/4 cup Oregon Grape root shavings
1/4 cup small pieces of Alder bark
2-300 ml beakers
6-150 ml beakers
1-500 ml beaker
300 ml of distilled water
6 small pieces of substrate (buckskin or real feathers)
1 pair of beaker tongs
Dropper bottle of 1 M ammonia (see Prep notes)
Dropper bottle of vinegar
2 glass-stirring rods
pH paper or other instrument to measure pH
Hot plate
1 paper towel

Summary
Students derive dyes from indigenous plants and test to see how changes in the pH of the dye bath affect the color of the substrate. Plants used are traditional dye sources of the native peoples living on the Flathead Reservation.

Objectives
The student will:
1) understand the concepts of anion, cation, ionization, ionic bond, salt, acid, base and pH.
2) learn to make and use traditional dyes used by the native people of the Flathead Reservation.
3) observe and understand how changes in pH affect the dying process.

Montana Science standards addressed
1) Students demonstrate knowledge of properties, forms, changes and interactions of physical and chemical sytems.
2) Students understand historical developments in science and technology .

Assessment
1) Evaluate the students' ability to work with others in successfully completing the lab.
2) Evaluate the students' ability to design and carry out the experiment using good scientific technique.
3) Evaluate the students' proficiency in accurately completing the written questions with the lab.
4) Evaluate the students' understanding of the concepts by giving short informal oral quizzes to each group as they are working.
5) Evaluate the students' understanding of the concepts by their write up of their results and hypothesis.

Procedural notes
1) Much of the background information and dying techniques for this lesson were taken from the excellent book The Chemistry of Natural Dyes by Dianne N. Epp, a publication of the Miami University's Center for Chemical Education. Complete information for this publication is provided below for those who would like more knowledge and/or additional activities about natural dyes.

The Chemistry of Natural Dyes, by Dianne N. Epp
Terrific Science Press
Miami University Middletown -Center for Chemical Education
4200 East University B1vd., Midd1etown, Ohio 45042
(513) 424-4444 x378 FAX (513) 424-4632
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2) This lab utilizes Mountain Alder and Oregon Grape, two plants commonly used by the Salish, Kootenai or Pend O'Reille people as dye sources. Service Berry, Rocky Mountain Juniper and Choke Cherry may also be used. The plant parts used and the color they render varies with the specific plant. Also, the color imparted by a specific plant will vary depending on many factors such as the substrate, the pH of the bath, the type of mordant used, etc.

   A) Oregon Grape (Berberis repens) -a yellow dye is made from root
   B) Mountain Alder (Ainus tenuifolia) -a brown dye is made from the bark
   C) Service Berry (Amelanchier alnifolia}- a violet dye is made from the berries
   D) Rocky Mountain Juniper (Juniperus scopulorum) -a brown dye is made from the needles, bark and berries
   E) Choke Cherry (Prunus virginiana) -a red dye is made from the juice of the cherries

   These are all fairly common plants in the Mission Valley but remember that generally it is illegal for a nontribal member to collect plant material on tribal land. When collecting the plants, please do so in a respectful manner. Plant parts such as bark and roots are available all year; while berries are available generally only in summer, so plan accordingly.

3) In order to finish the lab in one fifty minute class period, students should complete step #1 of the procedure prior to beginning the introduction to the lab, since the dyes must simmer for 30 minutes before use.

4) Be sure to use vinegar as the acid solution.

5) Because of the fume hazard, particularly from the ammonia, the lab must be done in a well-ventilated area, and preferably in a fume hood. A saturated baking soda solution, which does not create dangerous fumes, may be substituted as the base.

6) The teacher may choose to omit the simmering of the dye baths once the substrate has been added if equipment is limited. With a good strong dye solution, dying of the substrate will occur by simply allowing the substrate to sit in the solution for ten minutes, although results may be better with simmering, depending on the materials used.

7) Warn students not to touch, taste or smell any of the solutions. Acids and bases are a hazard to skin, clothing, eyes and respiratory system. The dye solution is a hazard because it is hot and can stain objects.

8) This lesson is easily adaptable to middle school. First, modify the lab write-up and especially the questions to an age-appropriate level. Second, substitute a saturated baking soda solution

as the base, instead of the ammonia. Third, consider omitting the use of the hot plate once the substrate has been added to the dye baths as noted in #5 above.

9) Arrange a visit for your students with an elder or tribal botanist knowledgeable about traditional plants. To find a suitable guest, call the culture committees, the Peoples' Center or the Natural Resources Department at the tribal complex. Ask the person to talk about plants with your students. Be aware that some topics, such as medicinal uses of plants, may be sensitive information, not suitable for transmission in all settings.

Further information

For further information about the plant dyes experiment or to obtain a middle school version of the lesson, contact Regina Sievert via electronic mail at wenonah@centurytel.net. For further information about the plants and their traditional uses, contact the Salish and Pend O'Reille or Kootenai Culture Committees.

References

Epp, D. (1995). The chemistry of natural dyes. Middletown, OH: Terrific Science Press.

Answer key

Introduction questions:

1) For example: hair, hides, porcupine quills, and feathers
2) Protein or polypeptide
3) Cation
4) Anion
5) H30+
6) Acid
7) Cation
8) The large number of free hydrogen ions bond with the substrate and most of the dye fragments sites, thus preventing the dye fragments from bonding with the substrate.
9) The number of free hydrogen and hydroxide ions present
10) Acid
11) Add base
12) Answers will vary

***Post lab questions*:**

1) A) Answers will vary depending on the materials used, but a pattern based on pH should be observable. B) The solutions which gave the deepest color probably had more dye fragments bonded to the ionic sites on the substrate.
2) A) amino acids B) NH2 C) ionization of water D) ionic E) a salt bridge F) more free H+ bind with NH2 to make positive binding sites, NH3+
3) Weak acid B) It takes a lot of vinegar to lower the pH. C) The strong acid would donate so many protons that they would bond with the substrate as well as the dye fragment, thus preventing the dye fragments from bonding with the substrate. D) The soapy base dissolves the bonds between the dye fragments and the substrate.
4) A) Native to an area, not introduced B) Serviceberry, Rocky Mountain Juniper, Choke Cherry

The Effects of pH on Plant Derived Dyes

Introduction

Dyes are organic chemicals that chemically bond to a material and give it color by reflecting specific wavelengths of light. They can be obtained from many sources, both synthetic and natural. Natural dye sources include plants, animals such as insects, and minerals. The native peoples living on the Flathead Reservation, for example, have traditionally used plants such as Oregon Grape, and Mountain Alder as dye sources.

1) As part of their tradition, the Salish, Kootenai and Pend O'Reille people of the Flathead Reservation use natural dyes. What types of substances are they coloring?

   A) C)

   B) D)

2) What type of molecule are all of the above substances made of?

Typically, the dye process takes place in a water bath. The plant parts containing the dye molecule are put in the water bath, where often the dye molecule ionizes. Next, the substance to be dyed, known as the substrate, is added to the bath. The charged dye fragment then forms a strong ionic bond with the substrate, coloring it. The dye fragment, depending on its chemical nature, may be a positive ion, a negative ion, or it may not ionize at all.

3) What is another name for a positive ion?

4) What is a negative ion called?

5) Fill in the blank in the equation below, which shows a typical way that a dye ionizes in water:

   dye--(SO_3H) + H_20 → dye--(SO_3^-) + _____

6) Because the dye in the above equation donated a proton (H^+), it would be considered an _____dye.

7) In this case, the negatively charged or anionic dye fragment would form a bond with a _____site on the substrate.

Most plant-derived dyes ionize into anionic dye fragments and so are called *acid dyes*. They tend to work better in slightly acidic baths because the free protons present bond to the substrate creating many cationic sites to which the anionic dye fragment can bond. If the pH is too low, however, this will inhibit the dye's ability to bond to the substrate.

8) Chemically speaking, how does a very low pH prevent the dye from bonding with the substrate?

In the following lab you will investigate how changes in the pH of the water bath alter the color achieved when dying a substrate. You will use natural plant dyes that are traditional dyes of the native people living on the Flathead Reservation.

9) What is pH a measure of?

10) What type of substance can you add to a liquid to lower its pH?

11) How can you raise the pH of a liquid?

12) What tool will you be using to measure pH?

NOTE

You will be using substances that can be harmful to your skin, eyes, respiratory system and clothing so be sure to **WEAR GOGGLES** and **EXERCISE EXTREME CAUTION**. **Do not smell the solutions at any time**!

Materials

Goggles for each group member
Shavings of the root of Oregon Grape -about 1/4 cup
Small pieces of Mountain Alder bark- about 1/4 cup
pH paper or other instrument for measuring pH
1-500 ml beaker filled with tap water
6 small pieces of a substrate to dye (buckskin or feathers)
Dropper bottle of 1 M ammonia solution
Dropper bottle of white vinegar
300 ml of distilled water
2 glass stirring rods
Hot Plate
1 paper towel
2 – 300 ml beakers
6 – 150 ml beakers
1 pair of beaker tongs

Procedure

1. Pour 150 ml of distilled water into each of the 300 ml beakers. Place the Oregon Grape shavings into one beaker and the Alder bark pieces into the other. Place the beakers on the hot plate and simmer the solutions for 30 minutes.

2. Label the 150 ml beakers to distinguish them from each other.

3. Carefully use the tongs to pick up the Oregon Grape beaker and decant the liquid equally into the three "A" beakers.

4. Repeat the procedure with the Alder solution, decanting the liquid into the "B" beakers.

5. Use the acid and base available to explore how changing the pH of each type of dye affects its dying abilities on a natural substrate. Leave the substrate in the dye for at least ten minutes, then remove it and rinse it in tap water.

6. Create a data table to record your results.

7. Write a summary of your results with a hypothesis to explain what happened in your experiments.

Post Lab Questions

1. A) Which two beakers probably had the most dye fragments bonded to the substrate?

   B) Give a chemical explanation for your answer to the question above.

2. Some typical substrates that native people might dye include hides, porcupine quills, hair and feathers. All of these substances are proteins, long chain polypeptides.

   A) What are types of substances are chained together to make a polypeptide molecule?

   B) What is a common functional group in a protein molecule?

   C) If the amino group on the protein substrate becomes a positive ion, an anionic dye fragment can bond to it. This can occur if the amino group bonds with a free proton in the water bath. Where would the free protons (H+) likely come from?

   D) What kind of bond is formed between an anionic dye fragment and a cationic site on the substrate?

   E) What type of substance is formed when an anion and cation bond in the dying process?

   F) How does lowering the pH in the dye bath create more binding sites for an anionic dye fragment?

3. In this lab you used vinegar to lower the pH of the dye bath.

   A) Is vinegar a strong or a weak acid?

   B) How can you tell?

   C) How would using a strong acid in the water bath affect the quality of the dying process?

   D) When washing clothes, is is recommended to separate dark and light colors to prevent dark dyes from ruining your light colored fabrics. Chemically speaking, what is your hypothesis for what is happening when soapy water (a base) causes dyes to run?

4. In this lab, we used indigenous plans as dye sources.

   A) What does the word indigenous mean?
   B) What other indigenous plants have been used traditionally by the native peoples living on the Flathead Reservation to make dyes