UV Blueprint Fabric Instructions

Introduction

Make your own UV-sensitive fabric and develop images of any object or pattern that you want! Take advantage of the ultraviolet-activated chemical reaction used in blueprinting to produce permanent images on a T-shirt or cloth.

Concepts

- Light-activated reactions
- Photochemistry
- Ultraviolet (UV) light

Background

The preparation of UV-sensitive cloth involves the combination of two iron salts—ferric ammonium citrate and potassium ferricyanide, $K_3Fe(CN)_6$. Exposing cloth that has been soaked in a combined solution of ferric ammonium citrate and potassium ferricyanide to UV light results in a reduction of iron(III) (Fe^{3+}) ions to iron(II), Fe^{2+}. This is an example of a photochemical reaction, a chemical change caused by light.

Iron(II) ions combine with hexacyanoferrate(III) ions from potassium ferricyanide, resulting in the characteristic dark blue color of the exposed part of a blueprint. The dark blue color is due to a mixed ferrous–ferric [iron(II)–iron(III)] compound, $Fe_4[Fe(CN)_6]_3 \cdot H_2O$. In areas where the cloth is covered by an opaque object (and protected from UV light), this reaction does not occur and the cloth remains its original color.

The overall reaction is

$$Fe^{2+} + [Fe(CN)_6]^{3-} \rightarrow \text{Prussian blue} \qquad \textit{Equation 1}$$

$$\text{where Prussian blue} = Fe_4[Fe(CN)_6]_3 \cdot H_2O$$

Prussian blue—also known as Turnbull's blue—has been shown by X-ray crystallography to be a mixed iron(II)–iron(III) compound that is best described as "ferric ferrocyanide," $Fe_4[Fe(CN)_6]_3$. The structure consists of a cubic array of iron ions with cyanide ions along the cube edges and water molecules in the cubes.

The general principle involved in making UV-sensitive fabric is similar to that used in the classic photographic process. Instead of iron salts, black and white photography uses silver salts coated on cellulose acetate paper. Silver is easily and quickly reduced from Ag^+ to Ag(s) when exposed to light. When film is exposed to light, the areas exposed to the most light form the most silver atoms and thus appear black on the negative. Areas that have not been exposed to light appear white on the negative because no silver ions have been reduced. The fixing and washing processes remove the excess reactants, preventing further darkening of the negative. Producing a black and white photograph from the negative involves shining light through the negative onto a fresh sheet of photosensitive paper.

Materials

Ferric ammonium citrate solution, $NH_4FeC_6H_7O_7$, 160 mL	Paper towels
Potassium ferricyanide solution, $K_3Fe(CN)_6$, 160 mL	Plastic bag, black
Cardboard insert	Soaking tub, plastic
Gloves, chemical-resistant	Stirring rod
Graduated cylinder, 500-mL	T-shirt or cotton cloth
Opaque or translucent objects and patterns	Tongs

**Ferric ammonium citrate is a complex salt of undetermined structure. It is composed of 16.5–18.5% iron, 9% ammonia, and 65% citric acid.*

Publication No. 11108
061616

Safety Precautions

The combined Prussian blue solution will dye the skin a dark blue. The Prussian blue solution is nontoxic; its color will fade with time. Dangerous hydrogen cyanide gas may result when potassium ferricyanide is heated or placed in contact with concentrated or strong acid. Never use potassium ferricyanide with acidic solutions. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

For best results, make solutions fresh the day of the lab. Solutions may be made ahead of time if stored in dark bottles away from light. The instructions provide enough solution for 30 students working individually.

1. To make 1 liter of ferric ammonia citrate solution, add 220 g of ferric ammonium citrate to 1000 mL of distilled or deionized water. Stir to dissolve. *Note:* This process will need to be repeated four times to obtain a total of 5 liters of solution (five batches of 1000 mL each) required for 30 students.
2. To make 1 liter of potassium ferricyanide solution, add 110 g of potassium ferricyanide to 1000 mL of distilled or deionized water. Stir to dissolve. *Note:* This process will need to be repeated four times to obtain a total of 5 liters of solution (five batches of 1000 mL each) required for 30 students.
3. Collect various objects and patterns to be placed on the T-shirts. Opaque or translucent objects work well.
4. Cut out a piece of cardboard that will fit inside the T-shirt top to bottom.

Procedure

Part A. Preparing a UV-Sensitive T-shirt

1. Use a 250-mL graduated cylinder to obtain 160 mL of the ferric ammonium citrate solution. Pour the solution into the plastic tub.
2. Use the same 250-mL graduated cylinder to obtain 160 mL of the potassium ferricyanide solution. Pour this into the plastic tub. Stir the solution well with the stirring rod.
3. Place the T-shirt in the solution in the tub. Mix the solution with a stirring rod to ensure the T-shirt is wetted completely through. Let the T-shirt soak for several minutes.
4. Set out paper towels or newspapers on the lab bench for the T-shirt.
5. With gloves on, remove the T-shirt from the solution and wring the excess solution out, doing this over the soaking tub. Spread out the T-shirt on the paper towels.
6. Place the T-shirt on a hanger. Place the T-shirt in a dark room to dry overnight.
7. Dispose of the soaking solution as directed by the instructor.

Part B. Developing Images on a Treated T-shirt

8. Remove the dried T-shirt from the hanger and place it in a black plastic bag.
9. Locate both a sunny area and a cloudy or shaded area outside.
10. Bring objects and patterns, cardboard insert and the treated T-shirt into the shaded area. Remove the T-shirt from the bag, place the cardboard sheet inside the T-shirt, and quickly place the object(s) or pattern on the T-shirt. *Note:* Doing this in the shade helps to block the T-shirt from direct sunlight.
11. With the object sitting on the treated T-shirt, move to a sunny area. Set the T-shirt in the sunlight, exposing it to bright, direct sunlight until the T-shirt turns a dark blue color. This step will take about 20 minutes on each side, depending on the brightness of the sunlight.)
12. After the T-shirt is developed, remove the objects and place the T-shirt back in the plastic bag. Bring it indoors (out of the sunlight). Wearing gloves and holding the T-shirt with tongs, rinse the shirt under cold water for a few minutes to remove the yellow color of excess iron(III) ions. Rinse until the rinse water is colorless and the T-shirt turns a lighter shade of blue.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Excess ferric ammonium citrate may be treated for landfill disposal according to Flinn Suggested Disposal Method #26a. Excess potassium ferricyanide solution may be oxidized according to Flinn Suggested Disposal Method #14. The soaking solution may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Structure and properties of matter, chemical reactions

Tips

- The T-shirts can be developed while still damp. Dry T-shirts produce a darker and more permanent blue color than those that are still moist and are also easier to manipulate. If drying the shirts overnight, select a room that can be darkened and where a pole can be placed to hang the shirts. Be sure to place absorbents or a drop cloth under the T-shirts to collect any drips.
- Any object that blocks the sun even partially will work. Photos and images can be printed and copied on overhead trans parency. When the shirt is developed, the image appears as a negative.
- You may want to try the procedure on cotton squares before the student lab. This will give you a good feel for the overall process before the students attempt it.
- The cardboard insert creates a flat surface for placing objects on the T-shirt. It also prevents UV light from filtering through the back of the material and developing the areas on the front.
- Always wear gloves when handling the shirts!
- If your situation prohibits students from going outside, try developing the T-shirts using an ultraviolet "black" light.
- When actual blueprints are made, instead of objects being placed directly on the paper, a sketch is drawn on colorless plastic and then placed over the blueprint paper before being exposed to UV light. The drawing forms white lines on the paper, which prevent the transmission of UV light and do not expose the photographic chemical in those areas.
- Plastic tubs can be shared, with students combining their soaking solutions and T-shirts. One liter of soaking solution will treat three T-shirts.
- Treated shirts should be washed using liquid laundry soaps or dish soaps. Powdered detergents can turn the blueprint to yellow.

Discussion Questions

1. Why is it best to store ferric ammonium citrate and other photographic chemicals in brown or dark-colored bottles?
2. Why does the lab work on overcast days as well as on clear days?
3. Why doesn't incandescent light (classroom lighting) develop the T-shirts?
4. Explain why blueprints or photographs may slowly deteriorate if they have not been rinsed well during development.

Materials for *UV Blueprint Fabric Instructions* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6879	Blueprint T-Shirts—Student Laboratory Kit
F0003	Ferric Ammonium Citrate, 500 g
P0051	Potassium Ferricyanide, Reagent, 500 g

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.