

# Tie Dye

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## **Background:**

- Students will be learning about dyes and fibers, how dyes and fibers interact, how to dye clothing, and designing an experiment to test the durability and fastness of the dye.
- Students should perform this lesson at the end of a full year of chemistry. Students must know and understand molecular structure and ionic and covalent bonds.

## **Standards:**

1. 1SC-P4 Create and defend a written plan of action for a scientific investigation.
2. 1SC-P6 Identify and refine a researchable question, conduct the experiment, collect and analyze data, share and discuss findings.
3. 5SC-P1 Predict chemical and physical properties of substances.

## **Objectives:**

- 1.1 Propose an experiment based on information provided that will test the fastness and durability of dyes that have reacted with cotton fibers.
- 2.1 Construct a researchable question on dye color fastness.
- 2.2 Employ a research design that incorporates a scientific method to carry out an experiment on color fastness of a tie dyed T-shirt.
- 2.3 Analyze experimental data to determine color fastness of a tie-dyed T-shirt sample.
- 2.4 Communicate experimental findings in a lab report.
- 3.1 Describe chemical and physical properties that are used to describe dyes and fibers.
- 3.2 Determine physical and chemical properties of dye and fiber interactions through observation and experimentation.

## **Materials:**

### **For Tie Dye:**

Interactive tie-dye computer module

White T-shirts in multiply sizes

Dye Fixer (sodium carbonate)

Large bakery buckets

Disposable gloves

Aprons

Safety Glasses

Urea

Fiber reactive dye powders in various colors

Rubber bands

Sponges

Zip-lock bags (1 gallon size)  
Paper towels  
Grocery sacks  
Plastic table coverings  
Instruction sheets  
Dishwashing soap  
Squirt bottles  
Deionized water  
Large beakers (at least 1000 mL)  
Gallon jugs (the type that milk comes in)  
Stirring rods or stir bars and stir plates  
Labels  
Permanent markers

**For Open Inquiry Experiments:**

Instruction sheet  
Tie-dyed T-shirts cut into squares  
Camera  
Tie-dyed T-shirts made by students  
Household items

**Time:** 2 days in-class time, 1 week outside of class

**Grade Level:** 10-12, undergraduate chemistry

**Procedure:**

**Set-up for tie-dye:**

Students should spend at least one day browsing through the Interactive Tie-dye computer module. This module is available in both PC and Mac versions. Questions that help guide the students and ensure they are attempting to absorb the information in the module are located with this document.

Set-up for the tie-dye begins well before the actual day of the tie-dye. Directions for the tie-dye are also located in the computer module. It is nice to have samples of tie-dyed t-shirts hanging around the room to set the mood.

White t-shirts can be purchased from a local store or ordered in bulk from companies such as Kayman T-shirts (1-800-488-4800). The t-shirts must be washed in hot water with one tablespoon of mild dishwashing liquid and dried in a hot dryer. Twelve T-shirts may be washed at a time. This washing process removes any lubricants, surfactants, or whiteners that were placed on the shirt during manufacturing.

Fiber reactive dyes can be ordered from Grateful Dyes (1-800-697-1566) in ~40 colors. Colors range in price from \$13 - \$41 per 5 pounds and can be ordered in quantities as small as 1 ounce (for a couple of dollars per color). To achieve a complete rainbow of colors the following dye colors are recommended: Red 9, Gold 34 (or Orange 22),

Yellow 38, Green 47, Sky Blue 56, Royal Purple 64. Many other colors are available and can be ordered by requesting a catalogue from Grateful Dyes.

The day that the tie-dye will occur will be a very busy day. The dye fixer (sodium carbonate) is prepared by adding 1.5 cups of dye fixer to 3 gallons of deionized water in a large bakery bucket. The sodium carbonate clumps when added to the deionized water, so the solution will need to be stirred. One bucket of dye fixer solution is necessary for each size of T-shirt to be dyed. The T-shirts need to soak in the dye fixer solution for 10-15 minutes before being dyed. This solution is slightly basic and removes the charge from the cotton fiber, allowing the dye to interact with the fiber.

Dye solutions must be prepared the day of the tie-dye. The dye powder is mixed into a solution of urea-water. Urea water is prepared by adding 2 cups of urea to one gallon of deionized water. This can be done in gallon jugs and stored for several months. The dye powders will be added to the urea water in large beakers. To make the colors in the shirts bright, at least four tablespoons of powder must be added to 1000mL of urea water. Slightly less or more dye powder may be used to make the colors lighter or brighter. The dye solution will need to be stirred for a few minutes because the dye tends to clump. In general, when six or more colors are available, one liter of dye solution will be sufficient to dye ~30 T-shirts. Unused dye solutions may be flushed down the drain and should not be kept. After the dye has dissolved, the solution may be transferred to a squirt bottle and labeled with the appropriate color using a permanent marker.

All surfaces that dyes will come in contact should be covered. Students also must wear rubber gloves. Any surface (skin included) that dye solutions come in contact with will become brightly colored and the color may not wash out.

When students are ready to tie-dye, the T-shirts can be removed from the dye fixer and wrung out. The T-shirt should be damp, but not drippy. (The exception to this is for the marble pattern.) The wetter the shirt is when the dye is applied, the more the dye will run or spread into areas where it was not applied. Students can spread their shirts out on one of the covered surfaces and fold or twist it into the desired design. The design is held in place by rubber bands. Design ideas are available on the Interactive Tie-dye Module. Dyes are added to the shirts until they are drippy wet. In order to achieve a shirt that has very little white in it, the folds of the shirt may be opened and squirted with dye. After dye has been applied, the shirt should be wrapped in paper towels and placed in a zip-lock bag. The outside of the zip-lock will need to be wiped off to prevent dye transfer and then placed in a grocery bag with the washing instructions and an extra pair of rubber gloves.

After everyone has dyed a shirt, the dye fixer solution can be washed down the drain with plenty of water. The room will need to be cleaned especially where the T-shirt buckets were sitting.

At least 24 hours must pass from the time that the shirts are dyed and when they are washed. This is to allow the dyes to fully react with the fibers. Green colors take longer

to react than other colors. Allowing more than 24 hours before washing will not ruin the T-shirt, it simply causes more blurring in the edges of the colors. To wash the shirt, remove it from the zip-lock bag while wearing gloves and unwrap the shirt from the paper towels. The shirt needs to be washed by itself or with a couple of other recently dyed T-shirts in hot water using 1 tablespoon of dishwashing liquid. The shirt must then be dried in a hot dryer. After this initial washing, the shirts can be washed with regular clothing detergent with other brightly colored clothes. The color won't fade.

**Inquiry Experiment:**

The next day in class, students should write down their research questions and proposals. Each student should design his or her own experiments that test the protective ability, durability, or color fastness of the dye after it has reacted with the t-shirt. Each proposal should include information on what the student plans to do to their t-shirt sample, how long they plan to expose the t-shirt sample to the experimental method, and how they plan to clean and dry the sample after treatment. All proposals need to be reviewed by the teacher to ensure that the students are not endangering themselves or others and to guarantee that the materials will be available to the student.

All student run experiments on t-shirt samples will be performed at home. This requirement has two purposes. First, it reinforces the idea that science is not just something that students and scientists do in the lab. Secondly, people purchase clothing and what we do to it eventually wears it out in some manner (holes, fading, stained). Therefore, the experiments performed should incorporate items that are in our houses and that the t-shirts may come into contact with, such as soda, salt, sun, soap, etc.

One week after the completion of the tie-dye, students should turn in a report of their experiments. Teachers could have students turn in portions of their report through the week, such as the procedure and any data collected. The reports should be typed and turned in with what remains of the t-shirt sample. The colors on the sample may or may not have changed, so the student should make a comparison of the color on the sample to a control in order to assess how much change has occurred. Students may need to refer back to the computer module for information as they write their reports. They can also find additional information on the Internet or in books at the school library.

The students should wear their t-shirts to class one day so that they can all compare their designs. Extra credit can be offered as an incentive to the students to wear the shirts.

## Interactive Tie-Dye Module Question Sheet

1. Compare and contrast the microscope images of wool, silk, and cotton. How does the structure of each affect the feel of the fabric they are made into?
2. Choose one of the dye structures (not procion orange) and draw it on this paper. Label the parts of the structure as they are labeled in the example of procion orange with W, D, Q, RG, and X.
3. Would the dyes used to tie-dye color your hair? Why or why not?
4. Why did only nobility in Japan used to be allowed to wear tie-dyed articles of clothing?
5. If a t-shirt is yellowish-orange, what colors and wavelengths of light is the dye absorbing?
6. Does cotton grow where you live?
7. What type of bonding has to occur between the dye and the fiber in order for the dye to remain attached to the fiber when the garment is washed?

Interactive Tie-Dye Module Question Sheet:

**Answer Key**  
**20 points total**

1. Compare and contrast the microscope images of wool, silk, and cotton. How does the structure of each affect the feel of the fabric they are made into?

**Wool has scales, cotton looks wrinkled, and silk is smooth. Wool feels rough, Cotton feels soft, silk feels slick.**

**(6 points, one for each observation)**

2. Choose one of the dye structures (not procion orange) and draw it on this paper. Label the parts of the structure as they are labeled in the example of procion orange with W, D, Q, RG, and X.

**Any structure can be used as long as it is not procion orange.**

**(6 points, one for the structure and one for labeling each portion)**

3. Would the dyes used to tie-dye color your hair? Why or why not?

**Yes, these dyes will react with a fiber and color it permanently. If they will dye wool, which is also a hair, then they will dye human hair.**

**(2 points)**

4. Why did only nobility in Japan used to be allowed to wear tie-dyed articles of clothing?

**The harvesting of silk was kept as a secret that only royalty knew and it was very expensive to obtain items made of silk.**

**(2 points)**

5. If a t-shirt is yellowish-orange, what colors and wavelengths of light is the dye absorbing?

**Blue and Blue Green, 435-500**

**(2 points)**

6. Does cotton grow where you live?

**Depends on the location of the students**

**(1 point)**

7. What type of bonding has to occur between the dye and the fiber in order for the dye to remain attached to the fiber when the garment is washed?

**Covalent**

**(1 point)**

Guidelines for Lab Report  
20 points

Introduction (3 points):

Explain the purpose behind the experiment being performed.

Materials (2 points):

Give a list of what materials were used in the experiment. Include the amounts of each substance used.

Methods (5 points):

Describe the experiment performed and give details of the procedure used for the experiment.

Observations (5 points):

Describe any changes (or lack of changes) noticed in the t-shirt sample during the experiment.

Claims (5 points):

Tell what you think happened to the t-shirt sample and explain why you think it happened.