# Colors In Chemistry!

***Using Paper Chromatography to Understand Polarity***

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**Field-tested with:** 11th grade Chemistry class, Watsonville High School (Winter 2014)

**Module Type:** Lab activity

**Duration:** 3 hrs: 1 hr vocabulary homework, 2 hr lab/class session

**Key Materials:**

* 6 strips per group of chromatography paper or white coffee filter (8 x 1.5 in strips)
* Watercolor markers (black, brown, purple, green) – Like Crayola classic markers
* 400-ml beakers (2 per group)
* Pencils and Colored pencils
* Popsicle sticks and Toothpicks
* Food dye coloring
* Small plastic tray for food coloring
* Metric rulers

**Concepts:** Electronegativity, Polarity, Solubility, Chromatography

**Skills:** Chemical analysis, Separation Chemistry, Paper Chromatography, Interpreting Results

**NGSS Standards**

 **DCI:** HS-PS1. Matter and its Interactions

 **Practices:** HS-PS1-3. Planning and Carrying Out Investigations; HS-PS1-2. Constructing Explanations and Designing Solutions

 **CCC:** 1. Patterns

**Overview:**

Students learn the skills of doing paper chromatography using both polar and nonpolar compounds. In addition students will also learn:

* How chromatography helps scientists test the components of different mixtures
* How solubility of polar and nonpolar substances differ depending on the solvent
* How to collect data during an experiment

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**Background for Teachers**

**Why this matters:** Chemistry teachers face a challenge when teaching students about chemical properties because molecules cannot be seen with the naked eye. It is often difficult for students to understand concepts such as atomic charge, molecular structure, or polarity without being able to see a molecule. By using language that creates models for students, and by performing a hands-on activity, students can see, and understand, the chemical differences between polar and nonpolar molecules. This module teaches students the skills needed to perform and analyze paper chromatography and gives them the background to understand gas chromatography, high performance liquid chromatography (HPLC), and column chromatography that they may encounter in more advanced chemistry courses.

**Assumed background:** Students should have a prior knowledge of color mixing and a basic understanding of color pigments. Students should be familiar with negative and positive charges in order to give them a background on which to base an understanding of polarity.

**Special context:** Mixtures are made up of more than one substance blended together without forming molecular bonds. The substance components have chemical properties of their own that allow us to separate the components. For example, a mixture of oil and water can be separated, since oil is not soluble in water and is less dense. Mixtures are often made of substances that vary in their solubility (and polar or nonpolar properties). This difference in molecular properties in a given substance will allow us to explore those properties while separating components of a whole.

**Scaffolding supplements:** For more information, there are many paper chromatography labs (largely non-inquiry based) online. Any of these labs can be used for more information regarding the activity.

<http://stem-works.com/subjects/10-crime-scene-investigation/activities/354>

<http://blogs.oregonstate.edu/hydroville/files/2014/06/paper_chrom1.pdf>

[http://www.sciencebuddies.org/science-fair-projects/project\_ideas/FoodSci\_p006.shtml - summary](http://www.sciencebuddies.org/science-fair-projects/project_ideas/FoodSci_p006.shtml#summary)

# Module Description

# Materials:

* 2 400 ml beakers per group
* Chromatography paper or white coffee filters (8 x 1.5 in strips per group - precut)
* Water
* Food coloring dye (yellow, red, green, blue) – pre-mixed to form black dye (~ 3 drops each)
* Water-soluble ink markers (black, brown, green, purple) – like Crayola classic markers
* Popsicle sticks
* Small plastic tray for food coloring
* Pencils and Colored pencils
* Toothpicks
* Metric rulers
* Lab coats and safety glasses

## Preparation:

* Chromatography paper or coffee filters should be cut into 8-inch strips (6 x 1.5 inches) in advance of the lab class period.
* Students should be given the vocabulary words listed in the Glossary section to define on flashcards the week before the lab activity takes place.

## Timeline:

1. Overview (PowerPoint with vocabulary review included)- 20 min
2. Lab set-up - 15 min
3. Inquiry lab - 50 min
4. Lab notebook questions - 20 min
5. Clean-up – 5 min

## Starting Point For Inquiry

Most students have mixed colors – either in art class with paints or otherwise. Teachers should introduce this module by discussing color mixing. They should then ask the students to think about how they would “unmix” the colors. This can be a lead-in to a discussion about the characteristics of individual color pigments, especially that some pigments/chemicals may be polar while some may be nonpolar, influencing their solubility.

Finally, teachers can provide real-world context to this module by giving examples of several professions that use chromatography on a regular basis! Biochemists use chromatography to separate scents or pigments, law enforcement uses chromatography to separate small amounts of drugs from urine or blood, and environmental managers use chromatography to separate trace amounts of pollutants from our water.

## Detailed Procedure

**1. Overview**

**PowerPoint –** The PowerPoint (Goetsch\_Chemcolors\_presentation.pptx) begins with an explanation of mixtures. It then introduces what paper chromatography is and how chromatography is used in different professions. Specifically, the PowerPoint introduces the concept of solubility and teaches the definitions of solute and solvent. Electronegativity is explained and it is shown how electronegativity causes some molecules to be polar. The concept of polarity is explained and how mixtures of dyes can be separated because the different dyes have different polarities. Different dyes or inks will show different solubility in the solvent based on their polarity. Solvents also have differing polarity: water (H2O) is very polar, whereas alcohol/ethanol is more non-polar. Organic chemicals such as acetone, hexanes, chloroform, and dichloromethane are even more non-polar.

Before the PowerPoint begins, students will label their lab notebooks with the following activity title and objective:

*Title: Colors in Chemistry: Using Paper Chromatography to Understand Polarity*

*Objective: To understand the difference between nonpolar and polar substances and to learn the skill or paper chromatography*

Throughout the PowerPoint, vocabulary words are introduced and students are given the chance to write down the vocabulary and the definitions in their notes. Alternatively, students could be given a vocabulary worksheet ahead of the class as homework, and the teachers could use the vocabulary in the PowerPoint as a review.

As the instructor proceeds through the PowerPoint, students will be asked to discuss the meaning of vocabulary words with a partner when these words are encountered. The instructor can ask students to explain terms, and give additional assistance if there are terms that students are still struggling to understand.

**3. Video Demo**

A video demo (see YouTube link below) of the chromatography lab with acetone will be shown to the class. The video will show the proper lab set-up to the students. It will also reemphasize the concepts they were just shown in the PowerPoint introduction. During the video, students will fill out the first page of the worksheet that accompanies this lab. After the video ends, a PowerPoint slide of the final acetone chromatograph will be put on the screen. Students are asked on their worksheet to make a graphical hypothesis using color pencils of how they would expect the chromatograph to look (with the same dye) using water (a polar solvent) instead of acetone (a non-polar solvent).

**2. Lab Set-up**

After having their graphical hypotheses checked by the teacher, the students will split into groups of 3-4 and move to their assigned lab station. One student from each group will get lab coats for each group member, while another student will collect the lab supplies from the instructor. Pre-mixed food dye will be available at the front of the room for the students to dot on their filter paper for the Food Dye Trial.

**4. Inquiry Lab**

Instructions for the students are provided in the lab worksheet (Goetsch\_Chemcolors\_worksheet.docx). The lab follows these steps:

**Food Dye Trial**

Step 1. Make a line on chromatography strip with pencil, 2 cm from the bottom.

Step 2. Add 50 ml of water (the solvent) into one graduated beaker.

Step 3. Use a toothpick to place a small drop of the food dye on the start line.

Step 4. Place the chromatography strip upright in the solvent and fold the top over the Popsicle stick. The solvent should not cover the start line or the dye spot.

Step 5. Wait for the strip to develop and remove from the solvent.

After completing the first trial, the students will tape or draw the results of the chromatography on their worksheet. They will then answer the question about their graphical hypothesis.

**Marker Trial – with green, purple, brown, and black markers for each group**

Step 1. Follow the instructions on the worksheet to set up the second chromatography strip.

Step 2. Place the second chromatography strip in the beaker with the water as before.

Step 5. Wait for the strip to develop and remove from the solvent.

After the marker trial, students will identify which of the markers matches each of the unknown on the final PowerPoint slide (Goetsch\_Chemcolors\_presentation.pptx).

**5. Clean-up**

Once an instructor has checked student’s worksheets, they should begin cleaning up their lab stations. Students will return lab coats to their hangers, and clean up any spills on the lab counter. Markers, extra filter paper, pencils, rulers, scissors, colored pencils and beakers will be returned to their lab kit. One student from each group will bring the lab kit to the front of the classroom to be checked by an instructor. Then they will return to their seats for the wrap-up.

**6. Lab Wrap-Up**

For the lab wrap up, the teacher will again review electronegativity and polarity using two example molecules, water and methane. The teacher will walk the students through drawing the structures of these molecules on the overhead projector, including number of protons, number of electrons and which levels they are in. The teacher will then draw the arrows showing the electronegativity and partial positive and negative charges of molecule. The instructor will then ask the students which molecule is polar and which is non-polar based on what they have learned in the activity.

## Assessment Methods

To assess whether students have mastered the skill, instructors will check each student’s worksheets during the lab activity. The following questions can be asked as the lab progresses:

1. Why do you hypothesize that the colors will look that way (according to their graphical hypothesis)?

2. Will the colors end up the same in a polar solvent (water) and the non-polar solvent (acetone) from the video?

Instructors will also ask the following questions about chromatography and polar/nonpolar substances:

1. Which colors are more soluble in water? Does this mean that they move higher on the paper or “fall-out” closer to the dot?

2. Which color markers have more polar pigments? Which have more non-polar pigments? How can you tell?

Correct answers given for each question show an excellent understanding, correct answers given for 2-4 questions show a satisfactory understanding, attempts to answer the questions show some understanding, and no attempts to answer the questions show that the student needs more explanation and assistance understanding the concepts.

## Possible pitfalls:

Care should be taken that students don’t stain their clothes or belongings (lab coats should be made available to students).

## Glossary:

**Mixture:** A compound made up of 2 or more substances that are not combined chemically.

**Electronegativity:** The amount of pull that one atom exerts on the electrons that it is sharing with other atoms.

**Polarity:** The separation of electric charge (positive and negative) in a molecule, which creates a dipole.

**Solvent:** a substance (usually a liquid) that dissolves something else.

**Solute:** a substance that dissolves in a solvent

**Solubility:** the chemical property referring to how difficult or easy it is to dissolve a substance in a solvent.

## Optional:

One purpose of this module is to develop the skill of using paper chromatography to separate components of different compounds by their polarity. The lab was specifically designed to be followed by the SCWIBLES-designed lab, “Elementary, my dear Watsonville!: Solving a Crime with Chemistry” where they will use paper chromatography among other techniques to analyze “evidence” from a crime scene.

# NGSS Standards

**Disciplinary Core Ideas**

HS-PS1. Matter and its Interactions

**Science & Engineering Practices**

HS-PS1-3. Planning and Carrying Out Investigations

HS-PS1-2. Constructing Explanations and Designing Solutions

**Cross Cutting Concepts**

HS-PS1,2,3,5. Patterns

**Supplemental Materials**

GoetschZuercher\_Chemcolors\_presentation.ppt

GoetschZuercher\_Chemcolors\_worksheet.docx

Link for Video Demo