ACS Chemistry for Life®

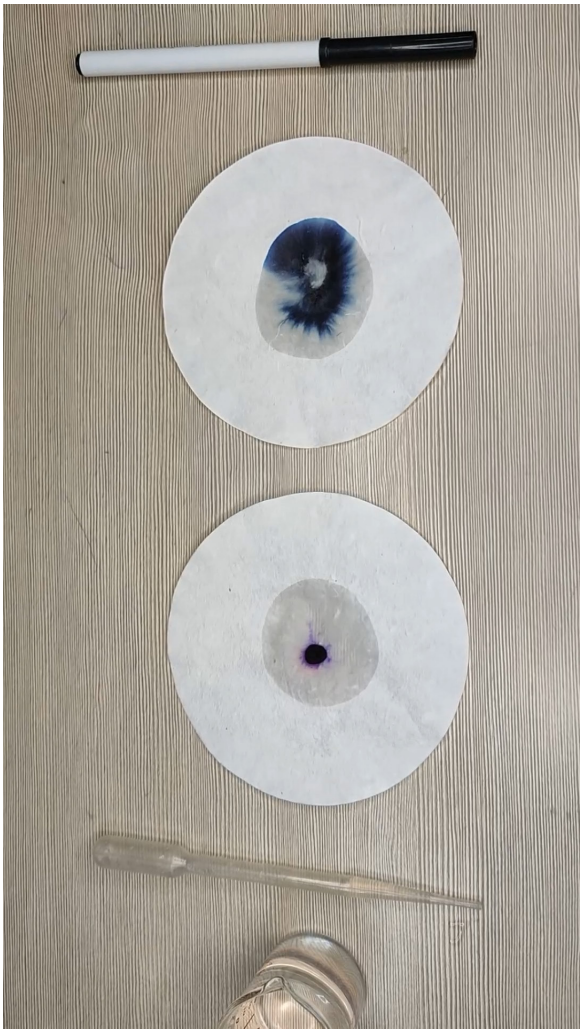
Small group

Mystery markers

Teach participants to use paper chromatography to uncover hidden colors in markers and make beautiful designs

Question to investigate

What colors are really used in markers?



Chemistry covered

- ***Mixtures:*** many markers contain a mixture of dyes to create their colors
- ***Intermolecular forces:*** different dyes in markers are attacted to water and paper to different degrees
- ***Chromatography:*** dyes in markers can be separated and identified using the different intermolecular forces between them, water, and paper

Special considerations

- Much of this activity is spent waiting for paper to dry. Prepare some samples in advance or have another activity for participants to do while they wait.
- Potential hazards include:
  - Broken glassware
  - Inhalation (isopropyl alcohol)
- Conduct your own RAMP assessment prior to presenting this activity.

Time required

Preparation: 10 minutes

Activity: 5 – 10 minutes (hands-on), 20 – 75 minutes (total)

Age range

5 – 12 years

Group size

- Participants work in pairs or trios
- 1 facilitator per 5 groups

Materials

***Per group**:*

- 4 – 6 filter paper disks (2 per participant), plus 2 for presenter
- 2 – 3 primary (blue, red, or yellow) and 2 – 3 secondary colored (green, purple, or orange) water-soluble markers (e.g., EXPO® Vis-à-vis®)
- 3 black water-soluble markers of different brands (e.g., Crayola®, Mr Sketch®, Mondo™)
- ~50 mL water in a paper cup
- 2 – 3 pipettes
- Art supplies (optional):
  - Hole punch
  - Colorful yarn or string cut into 6-inch lengths
  - Scissors
  - Chenille wires or pipe cleaners
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Additional materials identified in your RAMP analysis:

Prior to the activity

Customize activity to venue

1. Review RAMP safety worksheet for this activity.
2. Revise procedure to adapt to your specific venue and participants.
3. List appropriate procedures for accidents, emergencies:

Identify appropriate safety practices

- Wear appropriate personal protective equipment (e.g., goggles, gloves, etc.).
- Secure loose hair, clothing.
- Prohibit eating, drinking.
- Clean work area, wash hands after activity.
- Other practices identified in RAMP worksheet:

Prepare materials

Collect sufficient materials for all participants.

Prepare on site

For each group:

1. Provide 2 unmarked filter paper disks per participant, primary and secondary colored water-soluble markers, black markers, pipettes, and lids.
2. Set out art supplies.

Additional set-up for your specific venue and audience:

On-site activity

Step	Details	Ask participants:
Introduce activity	• Explain that participants will use paper to separate marker colors into their component dyes • The techniques used today are similar to those chemists use to analyze materials	• What do you know about primary and secondary colors? • What do you know about chromatography?
Make separate a secondary color	***Direct participants to:*** • Choose a primary (blue, red, or yellow) and secondary colored (green, purple, or orange) marker • Draw a few dots the the center of a filter paper disk. • Use the pipette to squeeze a few drops of water onto the filter paper directly onto the design. Explain how chromatography separates the components of the markers (see "Chemistry details")	• What do you guess will happen when you add water to the paper? • What actually happens to the ink as the water and moves on the paper? • Compare the two colors. How are they different?
Compare the color separation of the black markers	***Direct participants to:*** • Choose two of the three black markers • Draw an pea-sized dot in the center of a new piece of filter paper. • Add a few drops of water. Explain how chemists use chromatography to Identify the components of the markers (see "Chemistry details")	• Now what colors do you see? • What are the differences among the black markers? • Which black marker were you using?
Create your own art (optional)	• Use the art supplies to create bookmarks, butterflies, or other art	• What other products, besides markers, could you analyze using paper chromatography?
Clean up	• Dispose of all solids from this activity in the trash. • Dispose of all liquids down the drain. • Clean all work surfaces with water or a damp cloth. • Wash hands thoroughly.	

Chemistry details

Adjust these details to match the level of your audience.

IWhat is chromatography?

This activity uses an analytical technique called paper chromatography. The word "chromatography," was first used by Russian chemist Mikhail S. Tsvet, who combined the Greek words for "color" and "writing" to decribe the technique he used to separate mixtures of colored compounds.

Chromatography separates mixtures of compounds by passing a solution containing the mixture, called the "mobile phase" over a non-moving material, called the "stationary phase." In this activity, water is the mobile phase and the filter paper is the stationary phase.

As the mobile phase moves over the stationary phase, it carries the marker pigments with it. Pigment molecules move at different speeds depending on the size of the molecule and how attracted it is to the paper vs. the water. These differences cause the pigments to separate.

Separating secondary colors

Primary colors typically use one pigment, but secondary colors are made by mixing many different colors. For example, purple, which frequently relies on the food dyes Red #40 and Blue #1, separates into red and blue on the paper. (You can also use chromatography to analyze food dyes in drinks and candy.)

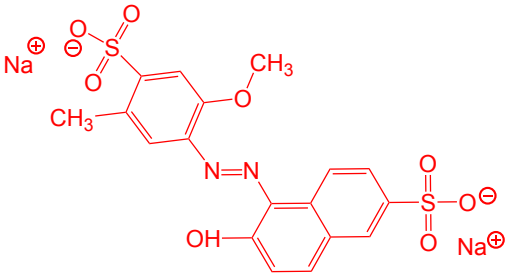
Separating black markers

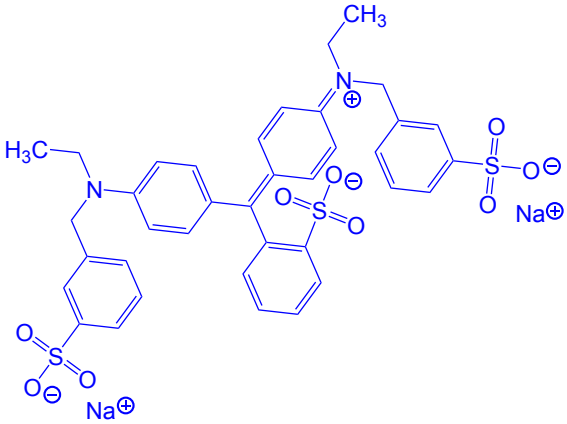
All of the different marker brands in this activity look black on the paper, but each company uses a unique mix of pigments. Chromatography reveals which colors combine to make which black marker.

Applications of chromatography

Chemists use a variety of compounds for the mobile and stationary phases to separate and analyze parts of mixtures with chromatography. Tsvet's oriiginal work used alcohol for the mobile phase and silicon dioxide to the stationary phase to separate the pigments that give plants their colors and show how they break down in cooler weather.

Chromatography can also be used by law enforcement in crime scene investigations, by art experts to determine original paint pigments in restoration projects, and even when analyzing food.





Red #40 (left) and Blue #1 (right) are food dyes that can be separated by paper choromatography. A complex combination of intramolecular forces enable the Blue #1 molecules to travel further in the mobile phase than the Red #40.

References

- American Chemical Society, 2023
- ACS International Student Chapter at Bombay College of Pharmacy
- Adapted from "Chemistry is Colorful" module of the Let's Do Chemistry series developed by the National Informal STEM Education Network, 2018. https://www.nisenet.org/catalog/chemistry-colorful (accessed September 2023)