Middle School Science Experiment

Solving Mysteries Using Paper Chromatography

Paper chromatography is a way to analyze mixtures, such as ink, by separating them into the original chemicals that are included in their makeup. Crime scene investigators use chromatography to identify and separate many different substances. Detectives often use chromatography to identify drugs from narcotics to aspirin in blood and urine. In this experiment, you will use chromatography to solve a make-believe mystery about the identity of a kidnapper.

Objectives

In this experiment, you will:

- Examine and compare ink samples
- View and photograph ink samples before and after separation
- Learn about ink and why it can be separated into different colors

Materials

- Power Macintosh G3 or better
- ProScope Digital USB Microscope and software
- Faded ransom note (see "Teacher information")
- Ink samples or watercolor black felt-tip pens (recommended brands: Mr. Sketch, K-Mart, Kodak, Crayola, Wal-Mart, Expresso Fine Tip, Flare Felt Tip, or El Marko by Flare)
- Piece of white paper
- Piece of white paper towel
- An additional white paper towel or a coffee filter
- Plastic cup or beaker
- Water
- Rubbing alcohol (optional)
- Salt or sugar (optional)

Procedure

Note to teacher: Place the ransom note on the board and explain that a school staff member has been kidnapped. Tell the students that the kidnapper left a ransom note in the school's mailbox, but it got wet, became faded, and the ink on the paper became diluted and ran. It is no longer readable. (See the "Teacher information" section for instructions about the preparation of the ransom note.) Tell students that FBI agents are on the way, but the principal has asked them to help solve the crime. You have narrowed the suspects down to six or eight (depending on how many pens you have). You have collected the pen each suspect was using, and now all the students have to do is determine which pen wrote the ransom note. Put the names of the possible suspects on the board. Put a picture from the ProScope USB microscope of the ink both before and after separation on the board next to the actual ransom note. You can either prepare samples with all of the pens and hand those out, or hand out pens to the students and have them prepare their own samples. Students should then follow these instructions:

1. Fill a plastic cup with water.
2. If you are using already prepared ink samples, carefully take the ink samples off the piece of white paper. Lay out the writing samples in order so they do not get mixed up. Using the ProScope USB microscope, take a picture of each ink sample using the x50 lens.

   If you are using the different pens to create the ink samples, you should each have a set of numbered pens and either a paper towel or a coffee filter. Cut small strips of the paper towel or coffee filter for use in your investigation. The strips should be approximately 1/4 inch by 1-1/2 inches. Put one dot in the middle of each piece of paper with a different pen. Keep the samples in the correct order. Using the ProScope USB microscope, take a picture of each ink sample using the x50 lens. Save the pictures for comparing and contrasting later.
3. Take the first paper towel and dip the end of it into the cup of water. Do not get the ink mark directly in the water. Let the paper towel absorb water until it reaches the ink mark. Hold it in the water for a few more seconds.
4. Place the wet ink sample on a dry paper towel. Put the samples in numerical order. Make sure they are placed neatly and spaced apart so the ink does not run onto the other samples. Repeat this procedure with all of the ink samples.
5. Let the wet samples sit on the paper towel for a few minutes until they begin to dry. Next, take a picture of each separated ink sample using the ProScope USB microscope. Compare and contrast the ink samples with the actual ransom note and the pictures on the board. Determine which pen wrote the ransom note.

Data

Describe the process used to identify the kidnapper. Explain how you were able to decide which pen wrote the ransom note. Describe how the pictures from the ProScope USB microscope helped you form your conclusion. In your report, include your selection of the kidnapper.

Processing the data

1. Were the inks used in the pens a compound or a mixture? Explain how you were able to determine the answer to this question.
2. Were the inks in the different pens all the same? Explain how you know the answer.
3. Why did the ink move up the paper towel?
4. Were you able to distinguish between the ink samples using the ProScope USB microscope? Explain how the samples looked through the microscope both before and after the separation of the ink.

Extensions

- Instead of using watercolor markers, use permanent markers and isopropyl (common rubbing alcohol) as the solvent. The watercolor and permanent markers could both be used, trying water first and then the isopropyl alcohol. You could write your own secret messages to each other and solve which pen wrote the message.
- You can also further experiment by adding salt or sugar to the water and testing the ink samples to see if there is any difference. Does this cause the movement of the ink on the paper towel to change? Is the method of separating the ink just as effective as the other method used?
- You can also test other colors in the same brand or in different brands of ink pens. Does one manufacturer of pens use the same colors in all of their different inks?

Teacher information

- To prepare the ransom note, you need a permanent marker and a watercolor marker. (The Mr. Sketch black marker works well for this.) Write the first part of the ransom note with a permanent marker so the ink will not run. Write the second part of the note with the black Mr. Sketch marker. Write the note on a piece of white paper towel. Write something to the effect of "I have kidnapped (Mr. or Mrs.) _____. Follow these instructions or something terrible will happen. No COPS! Put one million dollars in the garbage can behind the school after midnight. If this is done, (he or she) will be returned safely to you tomorrow." Put the bottom of the paper towel in water so the ink runs up the paper towel. The top half should be readable in the permanent marker, and the bottom half should be faded and the ink should be separated into its original colors. This gives the students something with which to compare their ink samples. Take pictures with the ProScope USB microscope both before and after the ink separation and place these on the board with the ransom note.
- Explain to students that ink spreads up the paper towel because the molecules in the ink have different characteristics. The size and solubility of the molecules allow them to travel at different speeds up the paper towel. The water is pulling the molecules as it acts as a solvent. The black ink contains several colors. When the water passes through the black ink sample, the molecules of the different colors move differently, forming the rainbow effect that is seen. Most common inks are water soluble and will spread out into the colors that make up that ink. This is the result of a physical change using the characteristics and physical properties of the ink. Separating the ink is a physical change.

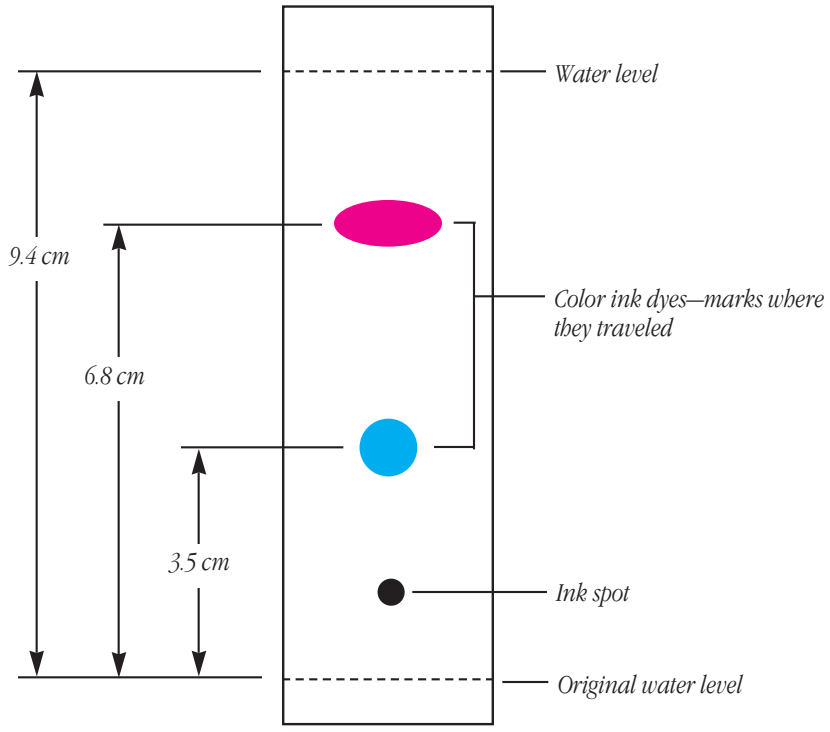
- This activity can also be used with high-level secondary school science students. These students can expand the chromatography experiment by calculating the retention factor of the specific dyes in the black ink and testing other colors of ink of the same brand. To do so, they would perform this additional step:

  Using the ink samples after the ink has separated, each separated spot can be assigned a retention factor (Rf). This factor is characteristic of the specific dyes in the black ink sample. The Rf is a ratio of the distance the color spot travels compared to the distance the solvent, or the water, travels. The Rf is calculated by dividing the color distance by the water distance. This ratio should be a constant for that specific dye on the medium used, coffee filter or paper towel, and the solvent. It should be able to be repeated in the same circumstances.

- The following is an example of calculating the retention factor of a specific dye. Actual tests on the inks used in the activity would have to be done to calculate the answers to the retention factors of the inks.

Calculations for the following diagram:

$$\text{Rf (magenta)} = \frac{6.8\text{ cm}}{9.4\text{ cm}} = 0.72 \qquad \text{Rf (cyan)} = \frac{3.5\text{ cm}}{9.4\text{ cm}} = 0.37$$



- An extension for secondary school science students is to test other color markers of the same brand to see if the colored dyes have the same retention factors in different colored markers. You should determine if the manufacturer uses the same dyes in all of their markers.

Sample results

The different ink samples will each separate into different colors and will result in different rainbow patterns. The pictures from the ProScope USB microscope will show differences in the ink samples both before and after the separation, but the differences before the ink separation will not be as easy to see. The pictures after the ink separation will show the differences in the ink by showing the rainbow patterns. You should be able to determine the kidnapper by identifying the pen that wrote the ransom note. The pattern formed by the Mr. Sketch marker should be the most distinct of all of the markers.

Answers to questions

1. The inks in the pens were a mixture because they could be separated easily. The different colors in the inks showed that the inks were made up of more than one component. The different colors traveled at different speeds up the paper towel, resulting in the rainbow patterns of the different inks. This is a physical property of the ink components and the ink samples.
2. The inks in the different pens were different because the patterns of the ink samples were very different. Some of the samples had many colors and some did not have many colors. Every ink sample separated differently.
3. The ink moved up the paper towel because of the water being absorbed into the paper towel. It worked as a solvent and separated the ink into its component colors.
4. The ink samples looked very similar in the ProScope USB microscope before the ink was separated. The lines of ink looked a little different, but not enough to make an identification of the correct pen. The ink looked very different after it was separated. The pictures enabled us to look at the colors very clearly.

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