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Candy Chromatography: What Makes Those Colors?

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Abstract

Quick, what's your favorite color of M&Ms® candy? Do you want to know what dyes were used to make that color? Check out this project to find out how you can do some scientific detective work to find out for yourself.

Objective

The goal of this project is to use paper chromatography to see which dyes are used in the coatings of your favorite colored candies.

Introduction

Have you ever had a drop of water spoil your nice print-out from an inkjet printer? Once the water hits the paper, the ink starts to run. The water is absorbed into the fibers of the paper by capillary action. As the water travels through the paper, it picks up ink particles and carries them along. This same process that spoils a perfect print-out can also be put to good use. There's even a name for it: paper chromatography.

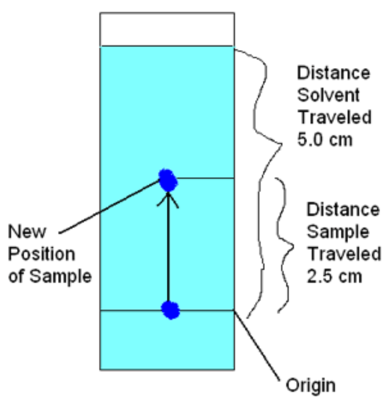
Chromatography is a technique used to separate the various components in a complex mixture or solution. It works because the components of the mixture will differ in how much they "stick" to things: to each other, and to other substances. For example, some of the components of the ink will stick more tightly to the paper fibers. They will spend less time in the water as it moves along the paper fibers, and thus they will not travel very far. Other components of the ink will stick less tightly to the paper fibers. They will spend more time in the water as it moves along the paper fibers, and thus they will travel farther through the paper.

Other materials than paper and water can be used for chromatography, but in each chromatography apparatus there is generally a *stationary phase* and a *mobile phase*. In paper chromatography, the paper is the stationary phase, and water is the mobile phase. Another example of a chromatography systems is a glass column filled with tiny, inert beads (the stationary phase). The mixture to be separated is added to the column, and is then "washed out" with some type of solution (the mobile phase). In this case, the separation is based on molecular size. Smaller molecules will pass through the spaces between the beads more easily, so they will come out of the column more quickly. Larger molecules will take more time to pass between the beads, so they will come out of the column later. You can separate the smaller molecules from the larger molecules by collecting the liquid that comes off such a column in a series of separate containers.

Chromatography can be used to separate (purify) specific components from a complex mixture, based on molecular size or other chemical properties. It can also be used to identify chemicals, for example crime scene samples like blood, drugs, or explosive residue. Highly accurate chromatographic methods are used for process monitoring, for example to assure that a pharmaceutical manufacturing process is producing the desired drug compound in pure form.

With colored mixtures in paper chromatography, you can see the components separate out on the paper.

To measure how far each component travels, we calculate the retention factor (R_f value) of the sample. The R_f value is the ratio between how far the component travels and the distance the solvent travels from a common starting point (the origin). If one of the sample components moves 2.5 cm up the paper and the solvent moves 5.0 cm, then the R_f value is 0.5. You can use R_f values to identify different components as long as the solvent, temperature, pH, and type of paper remain the same. In the image below, the light blue shading represents the solvent and the dark blue spot is the chemical sample.



When measuring the distance the sample traveled, you should measure from the origin (where the middle of the spot originally was) and then to the center of the spot in its new location.

To calculate the R_f value, we use the equation:

distance traveled by the sample component

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Project Summary

Difficulty	5 – 6
Time required	Very Short (a day or less)
Prerequisites	None
Material Availability	Readily Available
Cost	Very Low (under $20)
Safety	No issues

$R_f =$ distance traveled by the solvent

In our example, this would be:

$R_f = \frac{2.5\text{ cm}}{5.0\text{ cm}} = 0.5$

Note that an R_f value has no units because the units of distance cancel.

In this project, you'll use the R_f value to compare the "unknown" components of colored candy dyes with the "known" components of food coloring dyes. Since there are only a small number of approved food dyes, you should be able to identify the ones used in the candies by comparison to the chromatography results for food coloring.

Terms, Concepts, and Questions to Start Background Research

To do this project, you should do research that enables you to understand the following terms and concepts:

- Adhesion, cohesion forces
- Capillary action
- Paper chromatography
- Stationary phase
- Mobile phase
- Hydrophilic
- Hydrophobic
- Retention factor (R_f)
- Solvent
- Solution

Questions

- Why do different compounds travel different distances on the piece of paper?
- How is an Rf value useful?
- What is chromatography used for?

Bibliography

- This website is a good reference for basic chemistry concepts:
  Andrew Rader Studios, 1997–2007. "Chem4Kids," Chem4Kids.com [accessed July 17, 2007]
  http://www.chem4kids.com.
- Here you'll find an overview of liquids and capillary action:
  Microsoft Corporation, 2003–2007. "Liquids," Microsoft Encarta [accessed July 17, 2007]
  http://encarta.msn.com/encnet/refpages/RefArticle.aspx?refid=761571486&sec=18#s18.
- This is a good general reference on chromatography, written by a high school sophomore in an AP Chemistry course:
  VanBlaricum, A., 1997. "Chromatography," [accessed July 17, 2007]
  http://www.doggedresearch.com/chromo/chromatography.htm.
- This project idea is based on:
  Helmenstine, A.M., 2007. "Candy & Coffee Filter Chromatography," About.com:Chemistry [accessed July 17, 2007]
  http://chemistry.about.com/od/chemistryexperiments/ht/candychroma.htm.

Materials and Equipment

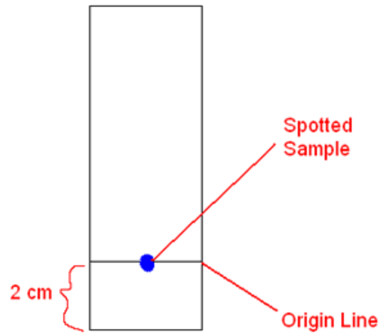
To do this experiment you will need the following materials and equipment:

- Candy with a colored coating, like Skittles® or M&Ms®
- At least 30 strips of paper
  - All strips must be exactly the same size.
  - 3 cm × 9 cm is a good size, but you can change this to fit your needs.
  - You can use white cone-type coffee filters cut into strips, or you can use chromatography paper.
- Wide-mouth jar
- Pencil
- Ruler
- Tape
- Salt
- Water
- Toothpicks
- Food coloring (red, green, and blue)

Experimental Procedure

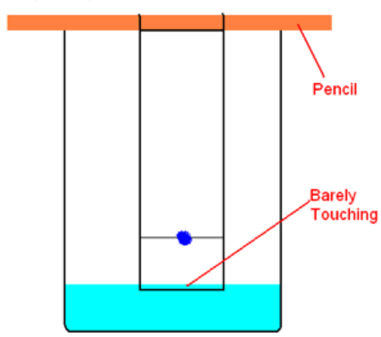
1. Do your background research so that you are knowledgeable about the terms, concepts, and questions, above.
2. Use a pencil to lightly label which candy color or food coloring will be spotted on each paper strip. Tip: do *not* use a pen for writing on the strips: the ink will run when the solvent passes through the strips.
3. Draw a pencil line 2 cm from the edge of each strip of paper.
   a. This will be the origin line.

b. You will spot the candy color for each strip right on this line, as shown below.



4. Next you need to extract some dye from each candy you wish to test.
   Set the candy down on a clean plate in a *single* drop of water. *Note:* If you use too much water, the dye will not be concentrated enough to see on the chromatography paper.
   a. Leave it for a minute to allow the dye to dissolve.
   b. Remove the candy, then dip a clean toothpick into the now-colored drop of water.
   c. Spot the candy dye solution onto the chromatography paper by touching the toothpick to the chromatography strip, right in the center of the origin line.
   d. Allow the spot to dry, then repeat the spotting at least three more times. You want to make sure to have enough dye on the chromatography paper so that you can see the dye components when they separate out on the paper.
   e. Make five separate strips for each candy you want to test.
5. Repeat step 4 for each color of candy you want to test (at least three different colors).
6. You also need to prepare chromatography strips with food coloring dyes.
   a. These will be your known compounds, with which you will compare the "unknown" candy dyes.
   b. For each food coloring color, use the same procedure as in step 4. You'll use a drop of food coloring as the source for dipping your clean toothpick.
7. Prepare a 0.1% salt solution for the chromatography solvent.
   a. Add 1/8 teaspoon of salt to 3 cups of water (1 g of salt to 1 L of water).
   b. Shake or stir until the salt is completely dissolved.
8. Pour a small amount of the salt solution into the wide-mouth jar.
   a. You'll tape the strip to a pencil and rest the pencil on top of the jar so that the strip hangs into the jar.
   b. The goal is to have the end of the chromatography strip just touching the surface of the solvent solution, as shown in the drawing below.

Paper Strip in Jar



9. Let the solvent rise up the strip (by capillary action) until it is almost at the top, then remove the strip from the solvent. Keep a close eye on your strip and the solvent front—if you let it run too long the dye may run off the paper and become distorted.
10. Use a pencil to mark how far the solvent rose with a pencil.
11. Allow the strip to dry, then measure the R_f value for each candy color (or food coloring) dye component.
12. Using the five repeated strips for each candy color (or food coloring), calculate the average R_f for each dye component.
13. Compare the R_f values for the candy colors and the food coloring dyes. Can you identify which food coloring dyes match which candy colors?

Variations

- For a chromatography experiment on separating the ink components from markers, see the Science Buddies project [Paper Chromatography: Basic Version].
- Try this project with a variety of candies—for example, does the red in Skittles® look the same as the red in M&Ms® when processed with chromatography? Is the average Rf value nearly the same? Look in the ingredients on each package to try and determine if the same dyes were used.

- For more advanced chromatography experiments, see the Science Buddies projects
  - Paper Chromatography: Advanced Version 1, and
  - Paper Chromatography: Advanced Version 2.
- For more science project ideas in this area of science, see Cooking & Food Science Project Ideas.

Credits

Andrew Olson, Ph.D., Science Buddies

Sources

This project idea is based on:

- Helmenstine, A.M., 2007. "Candy & Coffee Filter Chromatography," About.com:Chemistry [accessed July 17, 2007] http://chemistry.about.com/od/chemistryexperiments/ht/candychroma.htm.

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Career Focus

If you like this project, you might enjoy exploring related careers.

Chemist
Everything in the environment, whether naturally occurring or of human design, is composed of chemicals. Chemists search for and use new knowledge about chemicals to develop new processes or products.

Food Science Technician
Good taste, texture, quality, and safety are all very important in the food industry. Food science technicians test and catalog the physical and chemical properties of food to help ensure these aspects.

Chemical Technician
The role that the chemical technician plays is the backbone of every chemical, semiconductor, and pharmaceutical manufacturing operation. Chemical technicians conduct experiments, record data, and help to implement new processes and procedures in the laboratory. If you enjoy hands-on work, then you might be interested in the career of a chemical technician.

Food Scientist or Technologist
There is a fraction of the world's population that doesn't have enough to eat or doesn't have access to food that is nutritionally rich. Food scientists or technologists work to find new sources of food that have the right nutrition levels and that are safe for human consumption. In fact, our nation's food supply depends on food scientists and technologists that test and develop foods that meet and exceed government food safety standards. If you are interested in combining biology, chemistry, and the knowledge that you are helping people, then a career as a food scientist or technologist could be a great choice for you!

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