LESSON **17**

Separating Solutes

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Is this money genuine? Would you be able to find out by analyzing the ink that was used to print it?

INTRODUCTION

Most of the mixtures you have examined in this module have consisted of two substances. For example, the solutions you studied were mixtures of a solvent and a solute. In the last lesson, however, you investigated how different solvents could be used to remove more complex mixtures, or stains. The success of stain removal depended on the solubility of the pure substances that made up the stains. Two of the substances you tried to remove were inks. What was the composition of these inks? Were they both made from the same substances? If you made careful observations, you may have some clues to help you answer these questions. You may have noticed some strange things happening to the inks when you added some of the solvents. In this lesson, you will take a closer look at what happens when solvents are added to inks and how some of these properties can be used to identify inks from different sources.

OBJECTIVES FOR THIS LESSON

Use paper chromatography to analyze and identify inks.

Apply paper chromatography techniques to "solve a crime."

Getting Started

1. One member of your group should collect the plastic box.

2. Check the contents of the plastic box against the materials list and remove the apparatus for your pair. (In this lesson, you will work with a partner, but you will share the markers with the other pair in your group.)

3. Put about 25 mL of water into the 250-mL beaker.

4. *Quickly* (for about 1–2 seconds) dip the tip of the green marker into the water.

5. Observe what happens. Answer this question on Student Sheet 17.1: What happened when you put the tip of the green marker into the water?

6. Based on your observations, what do you know about the ink? Write your answer on the student sheet.

7. Your teacher will lead a short discussion about the observations you have made.

MATERIALS FOR LESSON 17

For you

- 1 copy of Student Sheet 17.1: Analyzing Inks
- 1 copy of Student Sheet 17.2: Comparing Inks
- 1 copy of Student Sheet 17.3: Identifying Inks
- 1 copy of Student Sheet 17: Assessment Review

For you and your lab partner

- 1 250-mL beaker
- 2 pieces of chromatography paper
- 1 pencil
- 1 metric ruler
- Access to water

For your group

- 1 brown marker
- 1 green marker
- 1 red marker
- 3 black markers (labeled B, C, and D)

Inquiry 17.1
Analyzing Inks

PROCEDURE

1. Empty the beaker you used in "Getting Started."

2. Put about 50 mL of water into the beaker.

3. Place a spot of green ink (about 2 mm in diameter) on one piece of chromatography paper, as shown in Figure 17.1.

4. Fold over the paper about 3 cm from the top.

5. Rest a pencil across the top of the beaker containing the water. Hang the paper on the pencil, as shown in Figure 17.2, for 5 minutes. Make sure the spot of ink is above the surface of the water.

6. Observe what happens to both the water and the ink. After 5 minutes, remove the paper from the beaker.

7. Draw your results on the "chromatography paper" on the student sheet. Under Step 4 on the student sheet, describe what you observed.

8. What can you conclude about the ink in the green marker? Write your ideas on the student sheet.

9. Contribute your ideas to a short class discussion.

10. Read "Introducing Paper Chromatography" on the next page.

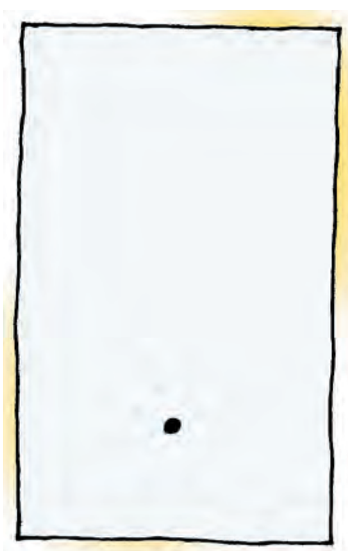

Figure 17.1 *Place the spot of ink in the position shown.*

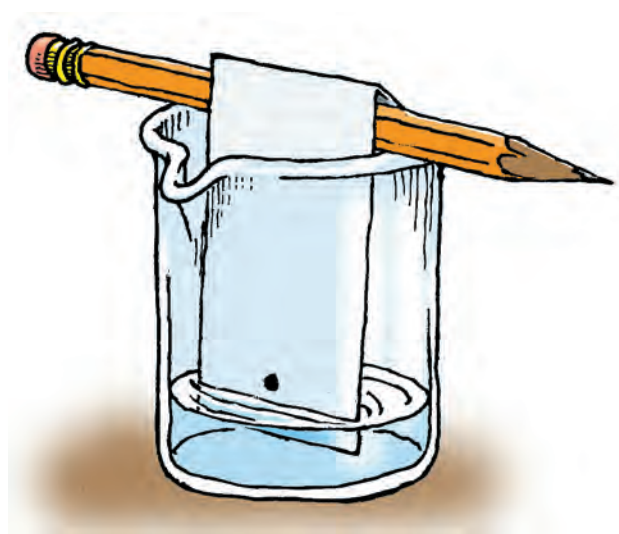

Figure 17.2 *Use a pencil to hang the paper in the beaker containing the water. Make sure the ink spot is above the surface of the water.*

INTRODUCING PAPER CHROMATOGRAPHY

The technique you used to separate the dyes in the green ink is called paper chromatography. The patterns produced on the paper are called a chromatogram. Chromatography works because the ink you used consists of several dyes of different colors that are dissolved in water. Each dye is a different solute and moves at a different speed through the chromatography paper. Just like cars traveling at various speeds on a highway, the faster solutes move ahead of the others and eventually become separated from them. The speed at which each solute moves through the paper depends on the solubility of the solute in the solvent (water). The more soluble dyes move faster than the less soluble ones.

Inquiry 17.2
Comparing Inks

PROCEDURE

1. How could you use chromatography to compare the *composition* of the inks in the green, red, black (B), and brown markers? You will need to make a fair comparison. Discuss this question with your partner. Your teacher will conduct a brainstorming session to come up with a class approach to this problem.

2. Use the procedure agreed on in class to compare the four inks. While you are waiting for the inks to move up the paper, write and/or illustrate the procedure under Step 1 on Student Sheet 17.2.

3. After the inks have moved up the paper, look at the chromatograms. Answer the following questions on your student sheet: What can you say about the composition of each color? Do dyes of the same color always behave in the same way? What does this tell you about these particular dyes?

Inquiry 17.3
Identifying Inks

PROCEDURE

1. Chromatography is a separation technique that is used for many purposes, including solving crimes. Read "The Case of the Unidentified Ink" on the next page. Then apply your knowledge of chromatography to find out whether a crime has been committed and, if so, to solve it.

2. Discuss with your partner how you are going to determine whether a crime has been committed and, if so, who committed it.

3. Outline on Student Sheet 17.3 the procedure you will follow.

4. Make sure your teacher approves your plan, and then conduct your investigation.

5. Record the results of your investigation on the student sheet as a description, a diagram, or a chromatogram.

6. Write a summary of your conclusions that can be presented in court.

7. Empty your beakers and return all of the materials to the plastic box.

REFLECTING ON WHAT YOU'VE DONE

1. You will discuss your findings in class. Some pairs will be asked to present their summaries.

2. Members of the jury in this case have no knowledge of chromatography. In your notebook, write two paragraphs: one explaining what chromatography is and the other how the process works.

THE CASE OF THE UNIDENTIFIED INK

Among the kinds of work that forensic scientists do is to help solve crimes by using a wide range of scientific techniques to gather evidence. Chromatography is one important technique that they use to catch criminals. In this inquiry, you will need to place yourself in the role of just such a scientist.

Exhibit A shows a check with a signature on it. Is the signature on the check a forgery? Was the check written by the owner or someone else?

There are three suspects in this case, each of whom uses a different pen. The only way to find out who signed the check is to analyze the ink in the signature and compare it with the ink in the pens handed over as evidence (Exhibits B, C, and D).

Pen B belongs to the owner of the checkbook, pen C belongs to a notorious criminal, and pen D belongs to a teller at the bank. Your lab assistant has already extracted some ink from the signature on the check and placed a spot of it on a piece of chromatography paper.

Who wrote the check? Was a crime committed?

Exhibit A: Is this check a forgery?

"Separation Science" at the FBI

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What does this building have to do with chromatography?

Two thieves rob a small-town bank of thousands of dollars. . . . A bomb explodes in Oklahoma City, killing more than 150 people. . . .

These two crimes are very different, but one of the techniques that crime detection experts use to investigate them is the same. It's called chromatography. One of the largest chromatography laboratories for crime detection is located in Washington, D.C., at the headquarters of the Federal Bureau of Investigation (FBI). Samples from crime scenes across the nation are sent to the FBI for forensic analysis. (Forensic analysis is a special type of scientific analysis that is performed in conjunction with legal or court proceedings.)

Many experts in forensic analysis work at the FBI. Some spend their time comparing fibers and hairs from crime scenes; others compare the soil from a suspect's shoes with the soil found at a crime scene. There are many rooms full of special equipment. Two of those rooms are dedicated specifically to chromatography. It is here that FBI Special Agent Kelly Mount works.

"Chromatography," explains Kelly Mount, a specialist in chromatography, "is a 'separation science.' It's the technique we use in our labs to separate the components of a mixture." Chromatography has many uses; it's not limited to crime detection. In fact, the first chromatography was done by a Russian botanist in 1906. He discovered that chlorophyll pigment could be separated from green leaves by passing an ether solution through a tube containing powdered calcium carbonate (chalk).

Mount uses a variety of substances to do this separation. Gases and liquids are the most common. Separating the substances, Mount says, is just the beginning of forensic analysis. "The purpose of chromatography is not to identify, but to separate," she emphasizes. Once scientists have their results, they have to compare them with the results of other analytical techniques before they can be admitted into evidence.

"Let's go down the hall and take a look at

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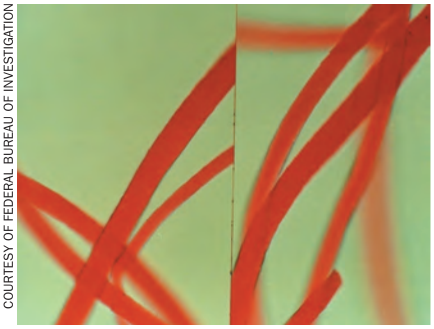

An FBI special agent uses a comparison microscope to compare fibers from a crime scene with those from the carpet in a suspect's car (above right).

two ways in which we use chromatography," Mount says. "The first one is simple and inexpensive—students do something similar to this in science class. The other one needs some sophisticated equipment.

"First, we'll take a look at how we use a simple form of chromatography, called thin-layer chromatography, to help track down bank robbers," she says. "Here's how it works. When banks bundle paper currency together, they routinely include a special security device inside some of the packs. This device has a miniature 'bomb' inside of it. When triggered, the bomb explodes. It doesn't do any damage to humans, but it does release a bright red liquid. The liquid is impossible to wash out."

When a robber says, "Hand over the cash," the bank teller obligingly turns it over, making sure to include a bundle of the specially packaged money. Soon after the robber leaves the bank, the device explodes, showering his or her car, clothing, or bag with the distinctive red dye.

The suspected criminal is sometimes caught "red handed." A sample of clothing or other material stained with the dye is sent to Kelly Mount's unit for analysis. Is it the dye from the security device? Or did the red color come from another source?

The chemical composition of the red dye used by banks is unique. No other dye has the same composition. Mount compares this dye of known composition with the dye found on a suspected criminal. She takes a crime scene sample of the material containing the dye and puts it in a solvent to extract the dye from the material. Mount then places several drops of the dissolved sample along a line at the bottom of a small, specially coated plate. (The thin coating on the plate is what gives thin-layer chromatography its name.) She puts the plate in a liquid. As the dots become moist and interact with the coating on the plate, they begin to move up the plate at different rates, depending on the solubility of the components. All dyes made from the same components will form the same pattern on the plate. So, if the crime scene sample matches that of the dye used by banks, another crime has been solved.

CORBIS/BRYN COLTON; ASSIGNMENTS PHOTOGRA

Chromatography is used by the FBI as a weapon against terrorism. Residues from terrorists' bombs, like the one that destroyed this aircraft, can be analyzed to determine the type and origin of the explosive used.

Bombs and Explosives

Chromatography also comes in handy for analyzing the materials used in bombs and explosive devices. The FBI analyzes samples from all major bombings involving the United States, including the one at the Murrah Federal Building in Oklahoma City and others causing airline crashes. The technique is called high-pressure liquid chromatography—HPLC, for short.

The first step is examination under a microscope. "Most bomb samples look pretty much alike. They look like black powder," says Mount. Even so, this first step is important. The scientists might, for example, be able to sort out small pieces of material from the residue.

The next step is extraction. The chemists place the sample in a solvent such as water. Once in solution, the particles in the sample may, depending on the composition of the sample, separate into smaller particles that carry positive or negative charges.

A small amount of the solution is placed in the HPLC machine. It moves up to the top, where it mixes with another liquid, and is then forced downward under pressure through a narrow glass column that is filled with a porous substance.

What happens in the column is the critical step. "Some of the [particles]," explains Mount, "seem to like it better in the tube than others. They stay longer."

The speed at which the particles leave the column is recorded by a detector, which then prints out the information. By comparing the time that the particles have stayed in the column with known retention times, Mount and her colleagues are able to distinguish the various types of particles in the test sample.

Still a Lot To Learn

Does it always work? "No," says Mount. "Sometimes we find nothing. And other times, we find nothing conclusive. It's also important to note that when it comes to explosive materials, HPLC is only a qualitative analysis technique. It helps us identify what materials are in an unknown powder. It doesn't provide quantitative information; in other words, we can't tell how much of each substance is in the powder."

Kelly Mount loves her work. To prepare for her career, she earned a bachelor's degree in chemistry and then went on to get a master's degree in forensic science. Life in the lab is never routine—this means getting called in to the lab on weekends or even at night when there is an emergency. Whether the problem is bombs or banks, Mount has the expertise to help the FBI solve its mysteries. ☐

QUESTION

What are the two types of chromatography mentioned in this reader? Use an encyclopedia, other library resources, and the Internet to find out more about these and other chromatography techniques.