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Catalog No. AP8554

Publication No. 8554

Stoichiometry of the Self-Inflating Balloon

Student Laboratory Kit

Introduction

Did you ever wonder how a self-inflating balloon works? Have fun investigating this novelty balloon with this activity! Apply stoichiometry and the ideal gas law to make your very own self-inflating balloon!

Concepts

- Stoichiometry
- Ideal gas law
- Limiting and excess reactants
- Acids and bases

Background

A self-inflating balloon is a sealed Mylar® balloon that contains sodium bicarbonate, also known as baking soda ($NaHCO_3$), and a packet of "water." The small packet of "water" is an aqueous solution of citric acid ($H_3C_6H_5O_{7(aq)}$). When the citric acid packet is broken, the chemicals react and inflate the balloon (Equation 1).

$$NaHCO_3(s) + H_3C_6H_5O_7(aq) \rightarrow H_2O(l) + CO_2(g) + Na_3C_6H_5O_{7(aq)} \qquad \textit{Equation 1}$$

In this lab, the contents and volume of a balloon will be analyzed to determine if the amount of baking soda is limiting or excess. The correct amount of baking soda and citric acid needed to inflate a balloon of your own creation to the correct volume will also be determined. The ideal gas law will be used to calculate the moles needed to inflate the balloon to the correct size (Equation 2).

$$PV = nRT \qquad \textit{Equation 2}$$

where

P = pressure (atm)
V = volume (L)
n = number of moles
R = universal gas constant
T = temperature (K)

Experiment Overview

The purpose of this experiment is to analyze the stoichiometry involved to determine the limiting reactant in a self-inflating balloon reaction. The data will be analyzed and applied in creating your own self-inflating balloon.

Pre-Lab Questions

1. Write out the chemical formulas for sodium bicarbonate and citric acid.
2. Write the balanced chemical reaction between sodium bicarbonate and citric acid.
3. What is the gas that inflates the balloon?

Materials

Citric acid, monohydrate, $H_3C_6H_5O_7•H_2O$
Sodium bicarbonate, $NaHCO_3$
Water, distilled or deionized
Balance, 0.01-precision
Barometer
Beaker, 600–mL
Forceps
Graduated cylinder, 100 or 1000–mL
Permanent markers, various colors
Pipet
Plastic bag
Scissors
Self-inflating balloon
Spatulas, 2
Thermometer
Transparent tape
Weigh dishes

Safety Precautions

Citric acid, sodium bicarbonate, and the contents of the self-inflating balloon may be irritating to skin, and especially irritating to the eyes. Sodium bicarbonate may be harmful if swallowed. Avoid contact of all chemicals with eyes and skin and wear chemical splash goggles, chemical-resistant gloves and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Observations with Instructor

1. Observe the teacher inflating one of the self-inflating balloons.
2. Observe an example of a self-inflating balloon made from a plastic bag.
3. Write down your observations of both balloons on the *Stoichiometry of the Self-Inflating Balloon Worksheet.*

Part B. Analyzing a Self-Inflating Balloon

4. Obtain a balloon from the instructor. Carefully cut a small opening into the balloon. *Note:* It is important to keep the opening small. You will be determining the volume of the balloon and need to keep it as intact as possible.
5. Carefully remove the aqueous citric acid packet using forceps.
6. Measure the weight of an empty, clean weigh dish.
7. Carefully remove the sodium bicarbonate solid and collect it in a weighing dish.
8. Weigh the weigh dish with the sodium bicarbonate.
9. Record the mass of only the sodium bicarbonate solid in Data Table 1.
10. Using water, fill up the self-inflating balloon and then pour the water into a 600-mL beaker,
11. Using a graduated cylinder, measure the water from the balloon and record in Data Table 1.
12. Determine the temperature and pressure in the room according to the teacher's instructions and record these values in Data Table 1.

Part C. Create Your Own Self-Inflating Balloon

13. Obtain a plastic bag. This will be your new self-inflating balloon.
14. Decorate the bag with permanent markers. See Figure 1 for ideas.
15. Find the volume of the plastic bag in milliliters (see steps 10–11). Record the volume in Data Table 2.
16. Dry the plastic bag.
17. Record the temperature and pressure of the room in Data Table 2.

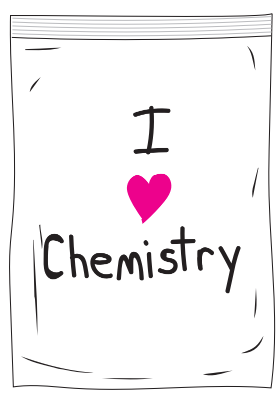

Figure 1.

18. Use the ideal gas law to calculate the amount of sodium bicarbonate and citric acid needed to inflate your balloon. Show your work on the worksheet and record the masses in Data Table 2.
19. Measure the solid sodium bicarbonate and solid citric acid.
20. Place the two solids in the plastic bag.
21. Take a pipet and cut all but 2 cm of the stem (see Figure 2).
22. Fill the pipet with water and carefully place it upright in the bag, so it does not spill.
23. Carefully seal the bag without releasing the water. Get as much air out of the bag as possible.
24. Transparent tape can be used around the edges to prevent leaking (see Figure 3).
25. Shake the bag so the water mixes with the two solids and they react. DO NOT squeeze the bag.

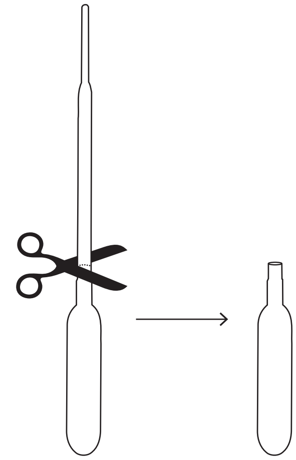

Figure 2.

Disposal

Consult your instructor for appropriate disposal proceedures.

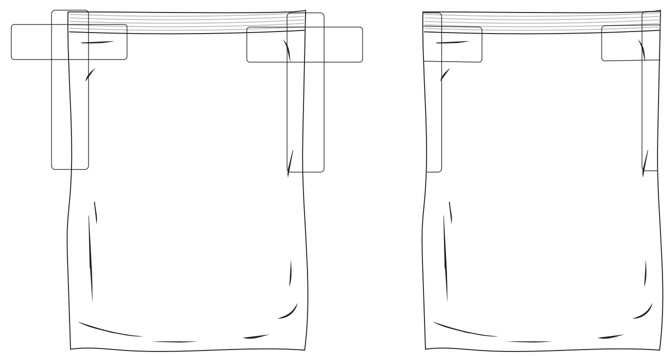

Figure 3.

Name: ____________________________________

Stoichiometry of the Self-Inflating Balloon Worksheet

Part A. Observations with Instructor

1. Record observations of the teacher's self-inflating balloon below.

2. Record observations of a self-inflating balloon made from a plastic bag.

Part B. Analyzing a Self-Inflating Balloon

Data Table 1.

Mass of empty weigh dish (g)	
Mass of weigh dish and sodium bicarbonate (g)	
Mass of sodium bicarbonate in balloon (g)	
Volume of balloon (mL)	
Temperature of room (°C)	
Pressure of room (atm)	
Calculated mass of sodium bicarbonate needed to inflate the balloon to the measured volume (g)	

3. Calculate the amount of baking soda needed to fill the self-inflating balloon full of carbon dioxide gas at room temperature and pressure. Show all work.

4. Was the sodium bicarbonate provided in the balloon limiting or excess in this reaction? Support the answer with evidence.

Part C. Creat Your Own Self-Inflating Balloon

Data Table 2.

Volume of plastic bag (mL)	
Temperature of room (°C)	
Pressure of room (atm)	
Mass of sodium bicarbonate needed (g)	
Mass of citric acid needed (g)	

5. Given the volume of gas needed to inflate the self-inflating plastic bag balloon, calculate the mass of sodium bicarbonate and citric acid needed to inflate the bag. Show your calculations below.

6. Record observations of the plastic bag self-inflating balloon below.

Post-Lab Question

7. To inflate a self-inflating balloon to a volume of 2.3 L at a room temperature of 25 °C, how much baking soda and citric acid would be needed?

Teacher's Notes

Stoichiometry of the Self-Inflating Balloon

Materials Included in Kit *(for 30 students working in pairs)*

Citric acid, monohydrate, $H_3C_6H_5O_7{\cdot}H_2O$, 100 g
Self-inflating balloons, 17
Sodium bicarbonate, $NaHCO_3$, 100 g
Pipets, disposable, 20
Plastic bag, 20
Transparent tape

Additional Materials Required

Water, distilled or deionized
Balance, 0.01 precision (may be shared)
Barometer*
Beakers, 600–mL, 15
Forceps, 15
Graduated cylinders, 100 or 1000–mL, 15
Permanent markers, various colors
Spatulas, 30
Scissors, 15
Thermometer
Weigh dishes, 15

*To measure temperature and pressure in room. See *Lab Hints* Section.

Pre-Lab Preparation

Create a model balloon for students out of a plastic bag. Best prepared the day of, an hour or more before class time.

1. Obtain a plastic bag and decorate it, using permanent markers (see Figure 1 on page 2 for ideas).
2. *Note:* The mass of reactants needed is dependent on the pressure and temperature of the room and the volume of the bag. The plastic bags included in the kit have an approximate volume of 0.560 L.
3. Read the temperature and pressure of the room using a thermometer and barometer.
4. Convert the units of pressure to atm if necessary.
5. Convert the units of temperature to units of Kelvin if necessary.
6. Use the ideal gas law to solve for the number of moles CO_2 needed. See *Lab Hints* for example calculations.
7. *Note:* The numbers used below will be different if your room pressure and temperature are different than 24 °C and 1 atm.
8. For a room at approximately 24.0 °C and a pressure of 1 atm, measure and place 1.93 g of sodium bicarbonate into the bag.
9. Measure and place 1.61 g of solid citric acid monohydrate in the bag.
10. Cut the long stem off of the pipet included in the kit. See Figure 2.
11. Fill the pipet full with water and gently place it in the plastic bag so it is upright and will not spill into the solids.
12. Seal the bag—removing as much air as possible.
13. Transparent tape can be used around the edges to prevent leaking. See Figure 3.
14. Shake the bag. DO NOT squeeze the bag.

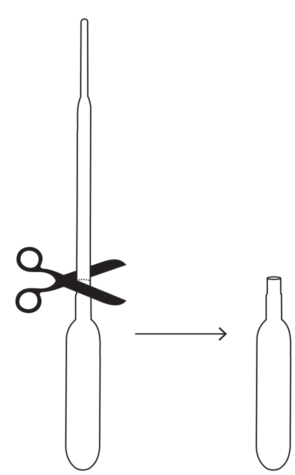

Figure 2.

Day of Lab

15. Present students with one of the self-inflating balloons.
16. Pass it around, let students look at it and record their observations (remind students not to activate the balloon).
17. Activate the balloon by pressing on the water packet inside. Shake.
18. Pass the self-inflating balloon around so students can feel that the balloon is cold. Allow students to shake the balloon. They can also listen and hear the reaction occurring inside.
19. Have students record their observations on the worksheet.
20. Display the pre-made plastic bag balloon for students to see.
21. Go over tips on making the plastic bag balloon. For example, how to tape the bag to secure it from leaking.

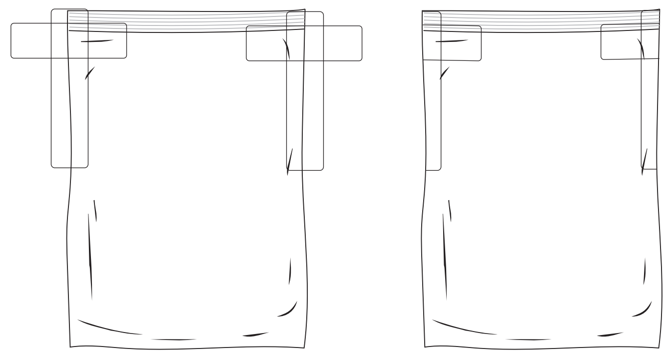

Figure 3.

Safety Precautions

Citric acid, sodium bicarbonate, and the contents of the self-inflating balloon may be irritating to skin, and especially irritating to the eyes. Avoid contact of all chemicals with eyes and skin and wear chemical splash goggles, chemical-resistant gloves and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Safety Data Sheets for additional safety, handling, and disposal information.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Solutions may be rinsed down the sink. Leftover solid sodium bicarbonate and citric acid may be placed in the trash, according to Flinn Suggested Disposal Method #26a.

Lab Hints

- Enough materials are provided in this kit for 30 students working in pairs, or for 15 groups of students. All parts of this laboratory activity can reasonably be completed in two 50-minute class periods. The *Pre-Laboratory Qustions* may be completed before coming to lab.
- Long forceps work best for removing the citric acid/water packet, such as Flinn Catalog No. AB1093.
- Students can use a large graduated cylinder to record the volume of the balloon and plastic bag or students can use a smaller graduated cylinder multiple times to record the volume.
- The mass of chemicals needed is dependent on the pressure and temperature of the room. To prepare the sample plastic bag balloon ahead of time, calculate the amount of chemicals needed based on the room's conditions.
- To take the pressure of the room, have students read from a barometer. If a barometer is not available, check the local weather stations for the pressure in the area. *Note:* Barometric pressure from a weather station is not the actual pressure, but has been adjusted for sea level. If the pressure is not given in atms, have the students convert the pressure to atms (1 inch = 2.54 cm, 10 mm = 1 cm, 1 atm = 760 mm Hg = 101.3 kPa = 14.6959 psi).
- Temperature needs to be in Kelvin for the ideal gas law calculations (K = °C + 273.15).
- Let students know that the solid citric acid used in the lab is citric acid monohydrate with a formula mass of 210.15 g/mol.

- The mass of reactants needed in Part C is dependent on the pressure and temperature of the room. The plastic bag has an approximate volume of 0.560 L. For a room at approximately 24.0 °C and a pressure of 1 atm, the amount of moles of CO_2 gas produced can be calculated using the following information:

$$PV = nRT$$

$$(1 \text{ atm})(0.560 \text{ L}) = n(0.08206 \text{ L}\bullet\text{atm}\cdot\text{mole}^{-1}\bullet\text{K}^{-1})(24.0 + 273.15)$$

$$0.560 \text{ atm}\bullet\text{L} = n(24.384 \text{ L}\bullet\text{atm}\bullet\text{mole}^{-1})$$

$$n = 0.02297 \text{ moles of } CO_2 \text{ gas}$$

$$3NaHCO_3 + H_3C_6H5O_7 \rightarrow 3H_2O + 3CO_2 + Na_3C_6H_5O_7$$

For every three moles of CO_2 produced, 3 moles of sodium bicarbonate is needed:

$$\frac{0.02297 \text{ moles of } CO_2}{1} \times \frac{3 \text{ moles of } NaHCO_3}{3 \text{ moles of } CO_2} \times \frac{84.01 \text{ g } NaHCO_3}{1 \text{ mole of } NaHCO_3} = 1.93 \text{ g } NaHCO_3$$

For every three moles of CO_2 produced, 1 mole of citric acid is needed:

$$\frac{0.02297 \text{ moles of } CO_2}{1} \times \frac{1 \text{ moles of } H_3C_6H_5O_7}{3 \text{ moles of } CO_2} \times \frac{1 \text{ mole } H_3C_6H_5O_7\bullet H_2O}{1 \text{ mole of } H_3C_6H_5O_7} \times \frac{210.15 \text{ g of } H_3C_6H_5O_7\bullet H_2O}{1 \text{ mole of } H_3C_6H_5O_7} = 1.61 \text{ g } H_3C_6H_5O_7\bullet H_2O$$

Teaching Tip

- Another fun activity is the *Exploring a Chemical Reaction in a Toy—Student Laboratory Kit,* Flinn Catalog No. AP7048. It's a great activity to do before this lab. Students identify the chemicals in the self-inflating toy through testing and acid–base chemistry. A video of this activity, *Bomb Bag,* is available at www.flinnsci.com as part of the Flinn Scientific "Best Practices for Teaching Chemistry" teacher resources videos.

Answers to Pre-Lab Questions *(Student answers will vary.)*

1. Write out the chemical formulas for sodium bicarbonate and citric acid.

   $NaHCO_3$ and $H_3C_6H_5O_7$ (or $H_3C_6H_5O_7\bullet H_2O$)

2. Write the balanced chemical reaction between sodium bicarbonate and citric acid.

   $3NaHCO_3 + H_3C_6H_5O_7 \rightarrow 3H_2O + 3CO_2 + Na_3C_6H_5O_7$

3. What is the gas that inflates the balloon?

   Carbon dioxide gas (CO_2)

Sample Data and Answers to Questions *(Student data will vary.)*

Part A. Observations with Instructor

1. Record observations of the teacher's self-inflating balloon below.

   The balloon became cold when activated. Fizzing could be heard inside the balloon.

2. Record observations of a self-inflating balloon made from a plastic bag.

   Make sure the edges of the plastic bag balloon are securely taped. Shake the balloon, do not squeeze the balloon.

Part B. Analyzing a Self-Inflating Balloon

Data Table 1.

Mass of empty weigh dish (g)	*2.30 g*
Mass of weigh dish and sodium bicarbonate (g)	*4.04 g*
Mass of sodium bicarbonate in balloon (g)	*1.74 g*
Volume of balloon (mL)	*378.0 mL*
Temperature of room (°C)	*23.7 °C*
Pressure of room (atm)	*1.00 atm*
Calculated mass of sodium bicarbonate needed to inflate the balloon to the measured volume (g)	*1.30 g*

3. Calculate the amount of baking soda needed to fill the self-inflating balloon full of carbon dioxide gas at room temperature and pressure. Show all work.

   $3NaHCO_3(s) + H_3C_6H_5O_7(aq) \rightarrow 3H_2O(l) + 3CO_2(g) + Na_3C_6H_5O_7(aq)$

   PV = nRT

   $(1\ atm)(0.378\ L) = n(0.08206\ L{\bullet}atm{\bullet}mole^{-1}{\bullet}K^{-1})(23.7 + 273.15)$

   $0.378\ atm{\bullet}L = n(24.359511\ L{\bullet}atm{\bullet}mole^{-1})$

   $n = 0.01551755\ moles\ CO_2$

   $$\frac{0.01551755\ moles\ of\ CO_2}{1} \times \frac{3\ moles\ of\ NaHCO_3}{3\ moles\ of\ CO_2} \times \frac{84.03\ g\ NaHCO_3}{1\ mole\ of\ NaHCO_3} = 1.30\ g\ NaHCO_3$$

   In order to inflate the balloon to 378.0 mL, 1.30 g of sodium bicarbonate is needed.

4. Was the sodium bicarbonate provided in the balloon limiting or excess in this reaction? Support the answer with evidence.

   1.74 g of sodium bicarbonate was included in the balloon. However, only 1.30 g of sodium bicarbonate was necessary for the balloon to inflate. Therefore, the sodium bicarbonate was in excess and the citric acid was limiting. If there had been more citric acid, the balloon could have burst.

Part C. Create Your Own Self-Inflating Balloon

Data Table 2.

Volume of plastic bag (mL)	*340 mL*
Temperature of room (°C)	*24.0 °C*
Pressure of room (atm)	*1.00 atm*
Mass of sodium bicarbonate needed (g)	*1.17 g*
Mass of citric acid needed (g)	*0.974 g*

Teacher's Notes *continued*

5. Given the volume of gas needed to inflate the self-inflating plastic bag balloon, calculate the mass of sodium bicarbonate and citric acid needed to inflate the bag. Show your calculations below.

   PV = nRT

   $(1\ atm)(0.560\ L) = \mathrm{n}(0.08206\ L{\bullet}atm{\bullet}mole^{-1}{\bullet}K^{-1})(24.0 + 273.15)$

   $0.560\ atm{\bullet}L = \mathrm{n}(24.384\ L{\bullet}atm{\bullet}mole^{-1})$

   n = *0.02297moles of* CO_2 *gas*

   $3NaHCO_3(s) + H_3C_6H_5O_7(aq) \rightarrow 3H_2O(l) + 3CO_2(g) + Na_3C_6H_5O_7(aq)$

   For every three moles of CO_2 *produced, 3 moles of sodium bicarbonate is needed:*

$$\frac{0.02297\ moles\ of\ CO_2}{1} \times \frac{3\ moles\ of\ NaHCO_3}{3\ moles\ of\ CO_2} \times \frac{84.01\ g\ NaHCO_3}{1\ mole\ of\ NaHCO_3} = 1.93\ g\ NaHCO_3$$

   For every three moles of CO_2 *produced, 1 mole of citric acid is needed:*

$$\frac{0.02297\ moles\ of\ CO_2}{1} \times \frac{1\ moles\ of\ H_3C_6H_5O_7}{3\ moles\ of\ CO_2} \times \frac{1\ mole\ H_3C_6H_5O_7{\bullet}H_2O}{1\ mole\ of\ H_3C_6H_5O_7} \times \frac{210.15\ g\ of\ H_3C_6H_5O_7{\bullet}H_2O}{1\ mole\ of\ H_3C_6H_5O_7{\bullet}H_2O} = 1.61\ g\ H_3C_6H_5O_7{\cdot}H_2O$$

6. Record observations of the plastic bag self-inflating balloon below.

   The balloon became cold when the reaction occurred. Fizzing was heard and bubbles could be seen inside the clear plastic bag. The bag increased in volume.

Answers to Post-Lab Question *(Student answers may vary.)*

7. To inflate a self-inflating balloon to a volume of 2.3 L at a room temperature of 25 °C, how much baking soda and citric acid would be needed?

   PV = nRT

   $(1\ atm)(2.3L) = \mathrm{n}(0.08206\ L{\bullet}atm{\bullet}mole^{-1}{\bullet}K^{-1})(25 + 273.15)$

   $2.3\ atm{\bullet}L = \mathrm{n}(24.45388L{\bullet}atm{\bullet}mole^{-1})$

   n = *0.094 moles of* CO_2 *gas*

   $3NaHCO_3(s) + H_3C_6H_5O_7(aq) \rightarrow 3H_2O(l) + 3CO_2\ (g) + Na_3C_6H_5O_7(aq)$

$$\frac{0.094\ moles\ of\ CO_2}{1} \times \frac{3\ moles\ of\ NaHCO_3}{3\ moles\ of\ CO_2} \times \frac{84.01\ g\ NaHCO_3}{1\ mole\ of\ NaHCO_3} = 7.62\ g\ NaHCO_3$$

$$\frac{0.094\ moles\ of\ CO_2}{1} \times \frac{1\ moles\ of\ H_3C_6H_5O_7}{3\ moles\ of\ CO_2} \times \frac{1\ mole\ H_3C_6H_5O_7{\bullet}H_2O}{1\ mole\ of\ H_3C_6H_5O_7} \times \frac{210.15\ g\ of\ H_3C_6H_5O_7{\bullet}H_2O}{1\ mole\ of\ H_3C_6H_5O_7{\bullet}H_2O} = 6.59\ g\ H_3C_6H_5O_7{\cdot}H_2O$$

Acknowledgment

Special thanks to Kathleen Dombrink, McCluer North High School, Florissant, MO for sharing this activity with Flinn Scientific.

The *Stoichiometry of the Self-Inflating Balloon Student Laboratory Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP8554	Stoichiometry of the Self-Inflating Balloon—Student Laboratory Kit
AP5070	Barometer, Metric
AP6049	Flinn Digital Pocket Thermometer, Economy Choice
AB1093	Forceps, Specimen, 10″
AP5394	Scissors, Student

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Publication No. 6149

Think Tube

Demonstration Kit

Introduction

What was it like to imagine the nature of the atom? How difficult is it to produce a model of something that can't be seen? The Think Tube allows students to appreciate the challenges associated with understanding things we can't see, such as atoms. As the instructor performs a series of simple manipulations with the Think Tube, students record their observations and later develop a hypotheses to explain the construction and inner workings of the tube.

Concepts

- Models
- Hypothesis

Materials

White tube, 18 inches long, 1.5″ in diameter, with 4 holes*
Cord, nylon, neon, 36 inches, 2*
Wood bead, 3/4-inch diameter, red*
Wood bead, 3/4-inch diameter, green*
Wood bead, 3/4-inch diameter, blue*
Wood bead, 3/4-inch diameter, yellow*
Washer, 3/4-inch diameter*
Tube caps, 2*
Think Tube Worksheet*

**Materials included in kit.*

Safety Precautions

The Think Tube is considered nonhazardous. Follow all normal laboratory guidelines.

Preparation

1. Loop the cords through a washer as shown in Figure 1. Place the washer in the middle of the tube.
2. Pull the ends of the cords through the holes of the tube (see Figure 1).
3. Pull the ends of the cords through the holes of the wooden beads and tie a knot at the end of the cords to hold the beads in place. Use the red bead in the upper left position, the yellow bead in the lower left position, the blue bead in the upper right position and the green bead in the lower right position (see Figure 1).
4. Cover the ends of the tube with the tube caps that have been provided.

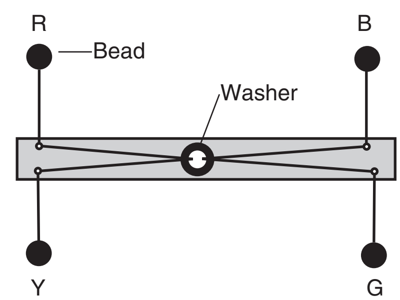


Figure 1.

Procedure

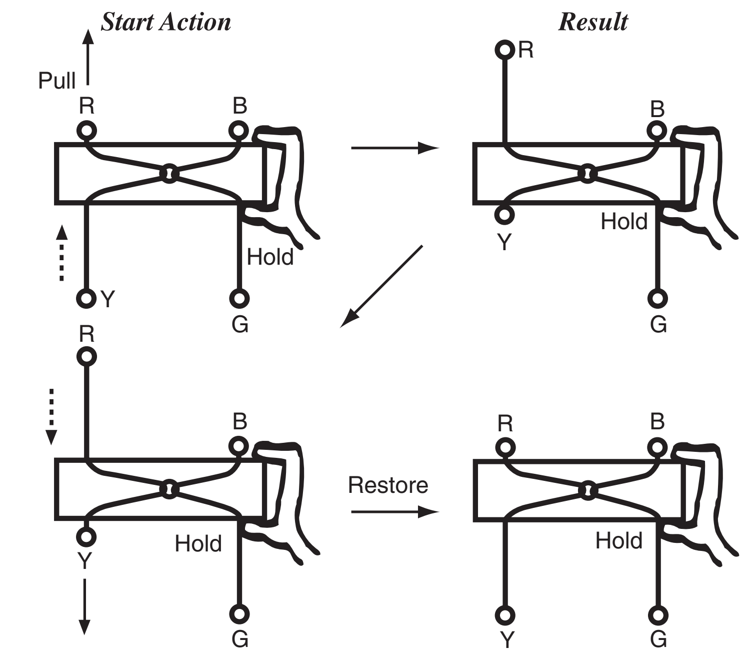
1. Pass out the Think Tube Worksheet.
2. Have students draw the original positions of the beads for each experiment in the left column of the Think Tube Worksheet.

3. The basic sketch for each manipulation should look similar the Figure 2. (R = Red bead; B = Blue bead; Y = Yellow bead; and G = Green bead)
4. In the middle column of the Think Tube Worksheet, students should draw or write what happened in each demonstration.
5. In the right column of the Think Tube Worksheet, students should draw or write their hypothetical explanation for each demonstration.
6. Perform the following four demonstrations. Be sure to pull the cord until it stops.

Demonstration 1

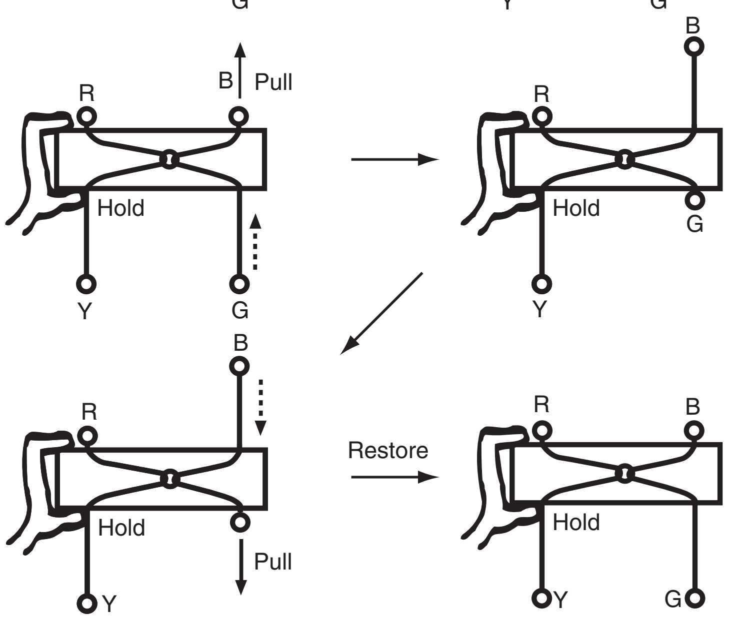
Red and yellow beads on left end appear to be connected by a single string.

1. Hold the cord attached to the green bead.
2. Pull the red bead.
3. Pull the yellow bead.



Blue and green beads on right end appear to be connected by a single string.

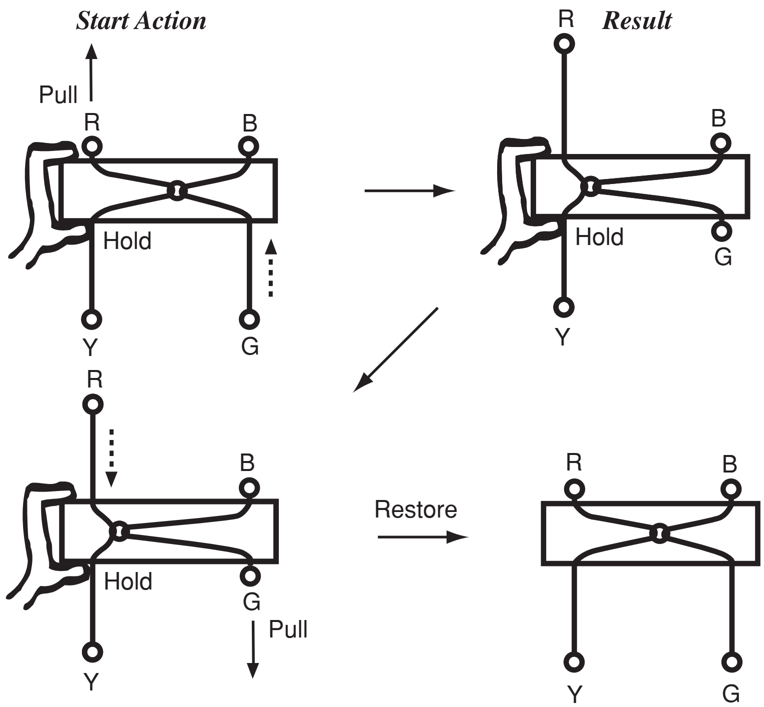
1. Hold the cord attached to the yellow bead.
2. Pull the blue bead.
3. Pull the green bead.



Demonstration 2

Red and green beads appear to be connected by a single string.

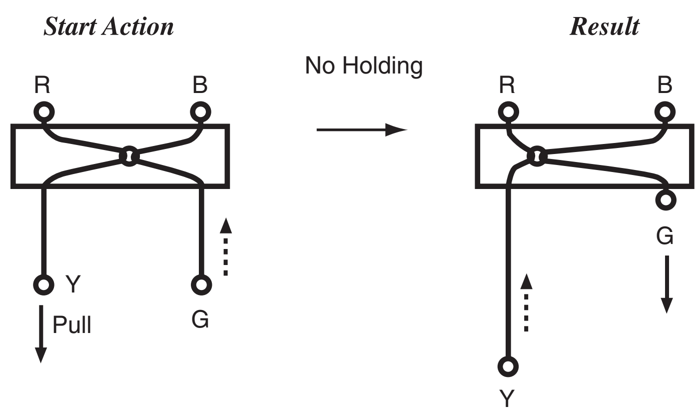
1. Hold the cord attached to the yellow bead.
2. Pull the red bead.
3. Pull the green bead.



Demonstration 3

Yellow and green beads appear to be connected.

1. Hold no cords.
2. Pull the yellow bead.
3. Pull the green bead.



Review:

Repeat any and all demonstrations and review what was observed.

Review should show that:

Demo 1: The red and yellow beads appear connected and the blue and green beads also appear connected.

Demo 2: The red and green beads appear connected.

Demo 3: The yellow and green beads appear connected.

So, it is pretty clear by now that the top and bottom strings on each end are not one single string.

Disposal

The think tube may be reused from class to class and year to year.

Tips

- This demonstration may be done as many times as desired.
- Practice each step of all four demonstrations before presenting the entire activity to the students. Some practice will be required to master all of the steps, especially holding the string at the holes without being obvious to students.
- The ends of the cords may be melted with the flame from a match to prevent fraying.

Discussion

The demonstrations presented in this activity are designed to create discrepancies in the minds of the viewers. In the first demonstration, it appears that the red and the yellow beads are directly connected together and that the blue and green beads are connected. In the second demonstration, the red and green beads seem to be attached to each other. The third demonstration seemingly illustrates that the yellow and green beads are also attached. Repeat the three demonstrations as many time as necessary for your students to develop a model. Some students may be able to describe in words better than draw what is occuring. Encourage both words and drawings to record observations and the model.

The goal of this demonstration is to have students hypothesize and develop a possible model of exactly what is happening. The demonstration may be presented as many times as you would like until students fully understand the mechanics behind the Think Tube. You may want to reveal the design at the end of the demonstration, or you may decide to keep the secret to yourself. Use your discretion!

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry

Acknowledgment

Special thanks to Robert Lewis, Downers Grove North High School, Downers Grove, IL, and Jeff Hepburn, Dowling High School, West Des Moines, IA, for providing the idea and instructions for this activity.

The *Think Tube—Demonstration Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP6149	Think Tube—Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Name: ______________________________

Think Tube Worksheet

A model is a representation of an object or process that cannot be directly observed. For example, we cannot see atoms but we can create models of atoms that are consistent with our observations. We cannot see what happens inside the brain as someone learns, but we can create models of how learning takes place.

You will see some demonstrations performed with strings coming out of a tube. You will use observations of how the strings work to create a model of the arrangement of strings inside of the box or tube.

After each demonstration, record what happened by drawing a diagram or explaining in words. After each demonstration, create a model of the string arrangement inside the tube.

	Original Position	**What Happened**	**Model**
Demonstration 1			
Demonstration 2			
Demonstration 3			
Review			

IN6149

Crazy about Chromatography

Introduction

Black is the lack of color–or is it? In this lab, you will separate three black ink mixtures from water-soluble, felt-tip pens or markers. Then, in the challenge activity you will produce a radial paper chromatography image.

Concepts

- Chromatography
- Separation of a mixture
- Physical properties

Background

Many common materials are made up of mixtures of compounds. Separating mixtures to determine the identity of one or more compounds has many practical applications in the fields of medicine, law enforcement, and manufacturing. It is often difficult to separate mixtures if the compounds are chemically similar. *Chromatography* is a technique used to identify and analyze components of a mixture.

Paper chromatography is a type of chromatography called adsorption chromatography. The paper acts as an *adsorbent,* a solid which can attract and stick with the components in a mixture (think of the word adhere). The solvent carries the materials to be separated through the adsorbent. In this lab, the solvent will be water.

The mixture to be separated is “spotted” onto the surface of the paper and water is then allowed to seep through the paper. As the components of the mixture dissolve in the water, they will travel up the paper at different rates depending on their physical properties. If one of the components in the mixture is more strongly attracted onto the paper than another, it will spend less time in solution and will move up the paper more slowly than the water. Components that are not strongly attracted onto the paper will spend more time in solution and will move up the paper at a faster rate. This separates the components and gives rise to different bands, depending on their physical attraction for the paper versus the solvent (water). If the components of the mixture are colored, the bands are easy to see.

Radial chromatography is a technique using a paper circle with a hole in the center. Ink is spotted onto the circle. A paper "wick" is inserted into the hole and then placed in a cup of water, making sure the paper circle does not come in direct contact with the water (Figure 1). The water seeps up the wick, then outward through the paper. The different pigments making up the ink mixtures will separate in a circular (radial) pattern. The resulting pattern is called a *chromatogram*.

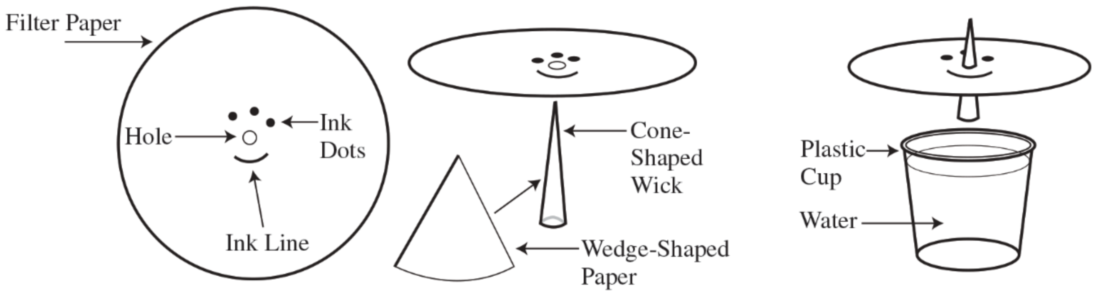


Figure 1. Radial Paper Chromatography

Experiment Overview

The purpose of this lab is to study the separation of mixtures by physical properties. In the introductory activity, students will investigate the ink of three black markers or pens. Then, in the challenge activity, students will produce a radial paper chromatography image based on their results from the introductory activity.

Materials

- Colored pencils (optional)
- Cups, plastic 30-mL, 2
- Cups, plastic 16 oz, 3
- Filter paper, 12.5 cm diameter, 4
- Graduated cylinder, 50-mL
- Markers and pens, black, water-soluble, various types, 3
- Paper clip (optional)
- Paper towels
- Pencil
- Ruler, metric
- Scissors
- Stapler
- Tape (optional)
- Water
- Wooden splints, 3

Pre-Lab Questions

1. Define the following three terms: chromatography, solvent, and adsorbent.

2. Draw a picture of the radial chromatography final set up and label all the parts.

3. What will be the adsorbent in this activity? What will be the solvent?

Safety Precautions

Although the materials in this activity are considered nonhazardous, please observe all normal laboratory safety guidelines. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Introductory Activity

1. Cut three strips of filter paper from one piece of filter paper, as shown below with the dotted lines in Figure 2.

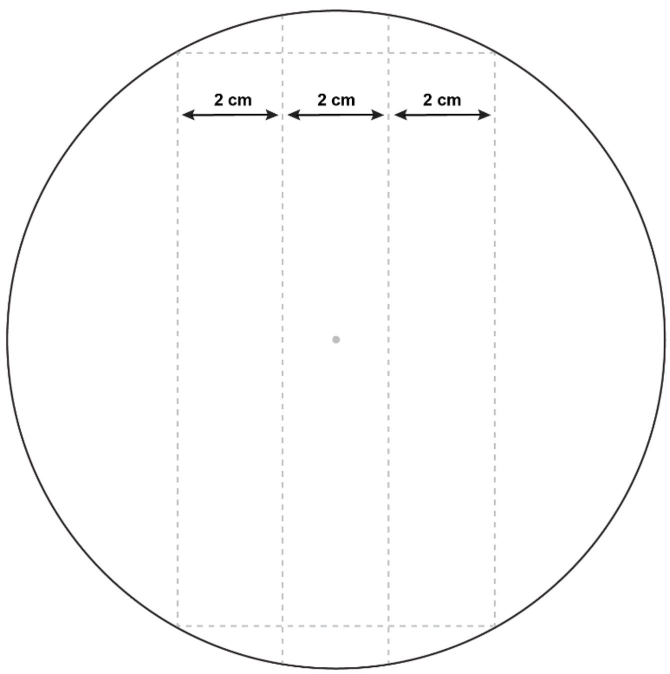


Figure 2. Cutting the Filter Paper Strips

2. Using a pencil, lightly draw a line across the width of each strip, 2 cm from one end (see Figure 3a).

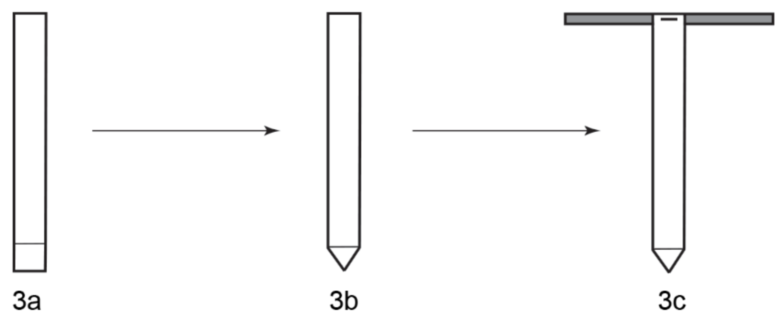


Figure 3.

3. Cut off the bottom corners of each strip to create a point, as shown in Figure 3b. Staple or tape the strip to a wooden splint as shown in Figure 3c. Repeat for all three strips.
4. Add 25 mL of water to each 16 oz. plastic cup.
5. Using a pen or marker, place a small dot on the center of the drawn line on one chromatography strip.
6. Using a pencil, label what pen or marker you used at the top of the strip or on the wooden splint.

7. Slowly lower one filter strip into the plastic cup. See Figure 4. The sample spot should remain above the solvent (the water). If it is not, your sample will dilute into the water. If the water is not high enough, remove the filter strip and add more water in 5 mL increments until the water touches the bottom point of the filter strip.

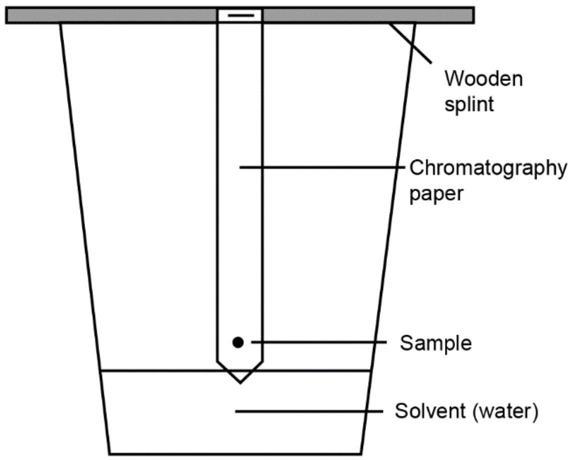


Figure 4.

8. Repeat steps 5-7 for two more different pens or markers (one pen/marker dot per strip).
9. Allow the filter strips to run until the water line reaches approximately 1 cm from the top of the paper (about 15-25 minutes).
10. Take pictures or sketch your results with colored pencils.
11. Share with at least two other groups to get the results of all eight markers.

Data Table 1.

Pen/Marker	Color(s) Observed	Photo or Sketch (with colored pencils)

Part B. Challenge Activity

12. Different designs and patterns can be made with radial chromatography. For example, see Figure 5 for two versions made with a variety of markers and pens.

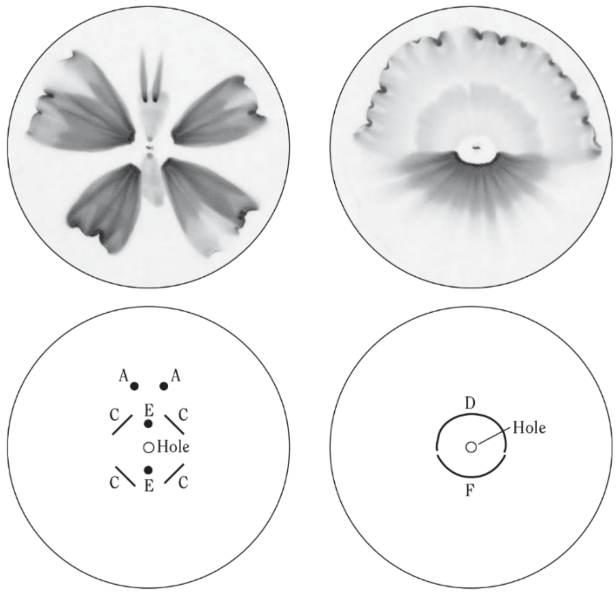


Figure 5.

13. The different letters, in Figure 5, correspond to different markers. Ink formulations are constantly changing, use what you discovered in Part A to decide what markers and pens to use to make your own artwork.
14. Your teacher also has some additional example artwork to reference for more ideas.
15. Discuss with your group and decide on two designs.
16. To make your radial chromatography designs follow the following steps:
   a. Obtain a piece of filter paper.
   b. Using a sharp pencil, paperclip, or pushpin, poke a small hole in the center of the filter paper.
   c. Fill a 30-mL plastic cup to within about 1 cm from the top with tap water.
   d. Starting at least 5 mm from the center hole, place a small but concentrated spot of ink from a water soluble marker or pen onto the paper. The "spot" may be a dot, a wedge, a short line, an arc, etc. See Figure 5 for an example.
   e. Obtain a wedge piece of paper from your teacher and roll up the filter paper wedge into a tight cone. Insert the cone-shaped "wick" into the hole in the center of the filter paper. See Figure 1 for reference.
   f. Set the prepared filter paper circle on top of the water-filled cup. When the water has advanced to within 1-2 cm of the outer edge of the filter paper (about 10-15 minutes), carefully lift the chromatography image and set it on a paper towel to dry.

17. Take a photo or sketch your artwork below. Use colored pencils, if desired.

18. If time allows, try making another radial chromatograph! Your group has enough supplies to make a total of three designs for this challenge activity.

Post Lab Questions

1. List the brand of each pen tested in this activity and record the colors observed. For each pen, list the colors (pigments) from least mobile to most mobile. The least mobile pigments will be the ones closest to the dots or lines made – these pigments have the greatest attraction to the paper. The most mobile will be closest to the outside or top edge of the papers.

2. Why does an ink separate into different pigment bands?

3. Do any of the pens or markers appear to contain common pigments? How can you tell if similar-colored pigments from different pens are actually the same compound? Do any similar-colored pigments appear to be different compounds?

4. Why were only water-soluble markers or pens used in this activity?

5. When the inks separate, is this a chemical change or a physical change?

Crazy about Chromatography Teacher Notes

Materials

Materials Included in Kit

- Chromatography challenge sample art
- Cups, Plastic 30-mL, 40
- Cups, Plastic 8 oz, 50
- Filter Paper
- Markers and pens, various types, 8
- Wood splints

Additional Materials Required

- Colored pencils (optional)
- Graduated cylinders, 50-mL
- Paper clips
- Paper towels
- Pencils
- Rulers, metric
- Scissors
- Stapler
- Tape (optional)
- Water

Prelab Preparation

Number or code all the markers and pens and place them in a central area for students to share.

For Part A, if desired, to save time you can cut the filter paper strips ahead of time for students. Each group will need three filter paper strips.

For Part B, you can make the wicks ahead of time, or have students prepare them. Each group will need at least three wicks.

1. Obtain a piece of filter paper and fold it in half three times to make 8 equal pie-shaped sections.
2. Using scissors, cut along the folds to make eight wedge-shaped pieces. These will be used for the wicks. If you have 15 groups performing the lab, you will need to cut at least eight filter paper circles into wedges.

Safety Precautions

Although the materials in this activity are considered nonhazardous, please observe all normal laboratory safety guidelines. Wash hands thoroughly with soap and water before leaving the laboratory.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. All solid materials may be disposed of in the solid trash according to Flinn Suggested Disposal Method #26a.

Lab Hints

- Enough materials are provided in this kit for 30 students working in pairs, or for 15 groups of students. Each group can make three radial chromatographs. Extra filter paper is included, if additional trials for Part A or B are desired.
- This investigation can be reasonably completed in two 50-minute class periods. The pre-laboratory assignment may be completed before coming to lab. One class period is needed for Part A and another class period for Part B.
- For Part A, depending on the length of the filter strips, students may have to add more water than 25 mL to the plastic cups. Add additional water in 5 mL increments without the paper in the plastic cup. Then, check to see if the paper reaches the water.
- The specific brands of pens included in the kit may vary depending on availability. Also, pen manufacturers can change ink formulations at any time. Since manufacturers may change ink formulations without notice, do not assume the art produced will match the sample art provided. Test the pens and markers beforehand to determine how the inks will separate.
- Allowing enough time for the development of the strip is important. The strips must be left in the plastic cups long enough for the water to be drawn up near the top of the strip.
- If a radial chromatography design is running too slowly or not at all, check to make sure the wick has been inserted snugly into the hole and that there is good contact between the wick and the inside edge of the hole. Typical running times are 10-15 minutes.
- Avoid excessive handling of the filter paper. Oils from the skin can interfere with the capillary action that draws the water through the paper.
- Additional different brands of markers and pens are commonly available at local stores. Experiment with a variety of water-soluble black markers or felt tip pens to determine the composition of each.

Teacher Tips

- Laminating the sample teacher art chromatograms will increase their durability and protect them from spills during the student procedures. These can be saved for future classes.
- To save laboratory time, filter paper strips and wicks may be cut by the teacher in advance. See Prelab Preparation section for more details.
- If an ultraviolet (UV or "black") light is available, shine it on the art chromatograms and chromatography strips. Some pigments will fluoresce under UV light.

Correlation to Next Generation Science Standards (NGSS)

MS-PS1-2: Analyze and interpret data on the properties of substances before and after substances interact to determine if a chemical reaction has occurred.

Data Table 1. Answers will vary.

Pen/Marker	Color(s) Observed	Sketch of Paper (with colored pencils)
Answers will vary.	Answers will vary.	Answers will vary.

Answers to Pre-Lab Questions

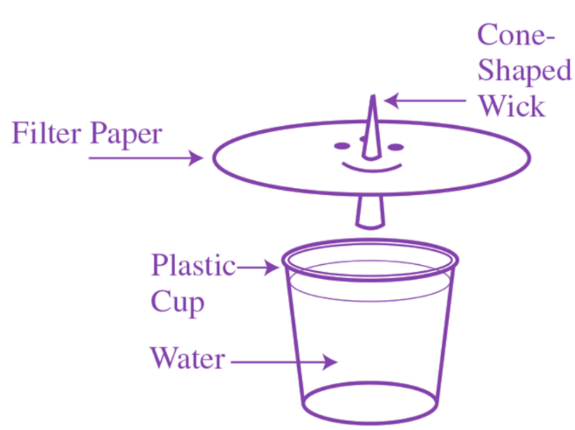
1. Define the following three terms: chromatography, solvent, and adsorbent.

   Chromatography is a technique used to identify and analyze components of a mixture.

   The solvent is a liquid that carries the materials to be separated through the adsorbent.

   The adsorbent is a solid that can attract and bind with the components of a mixture.

2. Draw a picture of the radial chromatography final set up and label all the parts.



3. What will be the adsorbent in this activity? What will be the solvent?

   In this activity, the filter paper will be the adsorbent and water will be the solvent.

Answers to Post Lab Questions

1. List the brand of each pen tested in this activity and record the colors observed. For each pen, list the colors (pigments) from least mobile to most mobile. The least mobile pigments will be the ones closest to the dots or lines made – these pigments have the greatest attraction to the paper. The most mobile will be closest to the outside or top edge of the papers.

   Remember, manufacturers may change formulations and pigments.

   Dick Blick: Black, gray, (green) blue, violet, lavender, yellow, pink
   EF: Lavender, pink, yellow, turquoise
   Le Pen: Brown, (yellow) purple, aqua
   Liquid Expresso: Dark midnight blue, gray, dark gray
   Mr. Sketch: Yellow, orange, rose, pink, turquoise
   Paper Mate: Purple, gray (yellow), blue, lavender
   Vis Aid: Gray, yellow-green, blue, lavender, purple
   Vis-à-Vis: Yellow-green, rose, purple, turquoise

2. Why does an ink separate into different pigment bands?

   Each ink is composed of different compounds. Each compound (pigment) has characteristic physical properties that will determine its relative attraction for the adsorbent (paper) versus the solvent (water) in this chromatography experiment.

3. Do any of the pens or markers appear to contain common pigments? How can you tell if similar-colored pigments from different pens are actually the same compound? Do any similar-colored pigments appear to be different compounds?

   Several of the pens and markers appear to contain similar pigments. The turquoise in the Vis-à-Vis, Mr. Sketch, and EF pens may be the same compound because they seem to have the same mobility—this pigment traveled the farthest in all three pens. The blue pigment in the Paper Mate, Vis Aid, and Dick Blick also may be the same compound. The yellow in the EF pen is quite mobile whereas the yellow in the Mr. Sketch pen has much greater attraction to the paper—these pigments are most likely different compounds.

4. Why were only water-soluble markers or pens used in this activity?

   The ink must dissolve in the water in order to migrate with the water through the paper. If the ink does not dissolve, the ink spot will remain at the origin and will not separate into different color bands.

5. When the inks separate, is this a chemical change or a physical change?

Separating the ink is a physical change. The pigments did not change chemically, they were physically separated by chromatography. Some were more attracted to the paper and others were more attracted to the water. No chemical changes occurred.