**Introduction:**

Paper chromatography is a powerful technique used for separation. The basic idea is that a small spot of a mixture is placed on a piece of chromatography paper where it is absorbed by the paper. The bottom of the paper is then placed in a solvent. The solvent moves up the paper by capillary action, which occurs as a result of the attraction of the solvent molecules to the paper and to one another. As the solvent passes through the sample mixture, some parts of the mixture may be attracted to the solvent and follow it up the paper. Different types of molecules are transported different distances, depending on their attraction to the solvent or the paper, thus causing them to separate. Molecules that are strongly attracted to the solvent travel farther than molecules that are weakly attracted to the solvent.

**Standards Addressed:**

Physical Sciences

1f. Students know differences in chemical and physical properties of substances are used to separate mixtures and identify compounds.

Investigation and Experimentation

6h. Students will draw conclusions from scientific evidence and indicate whether further information is needed to support a specific conclusion.

6i. Students will write a report of an investigation that includes conduction tests, collecting data or examining evidence and drawing conclusions.
Background:
Do the following lessons before this lesson plan:
1. Mystery Powders
2. Movement of Molecules in Hot and Cold Water using Food color
Do activities or demonstrations to show the attractive force between water molecules and that water is polar:
1. Jumping paper
2. Bending a stream of water
Students complete the word analysis chart. Before this lesson, help students learn and remember the vocabulary: Do activities, demonstrations, or show images – then students are ready to play Bingo.

Time Frame:
Teacher Preparation: 10 minutes
Activity 1: An Impossible Separation? 10-15 minutes
Activity 2: Separating Food Coloring 20-30 minutes
Activity 3: Mystery Pen 20-30 minutes

Vocabulary:
Absorb (absorption): To take up by capillary action or chemical action. A liquid or solid material can absorb particles of gas or liquid. For example, a sponge absorbs water.
Capillary Action: The natural movement of a liquid as it is pulled upwards through tiny spaces in a material. Paper towels absorb liquid through capillary action.
Chromatogram: The visual pattern formed by substances that have been separated by chromatography.
Chromatography: A technique used to separate mixtures into their individual components.
Magnet: A device that produces a magnetic field that attracts iron and other magnetic materials including nickel, some steels and the mineral magnetite, Fe₃O₄.
Magnetic: Capable of being magnetized or attracted by a magnet.
Mixture: A combination of two or more substances that are not chemically united. No chemical reaction occurs between the substances in a mixture.
Solvent: A liquid that dissolves a solid, liquid or gas resulting in a solution. The most common solvent in everyday life is water.
Solution: A homogenous mixture of two or more substances. For example, a solid such as salt, dissolves in water to make a homogeneous solution.
Soluble: Able to dissolve to a significant extent in a given volume of solvent.
Dissolve: The process of a substance becoming mixed uniformly into another substance. For example, a solid substance dissolves in a solvent to yield a solution.
Substance: A particular kind of matter or material; a solid, liquid or gas with particular properties.
Attraction: (attract) The ability to make things move toward each other.
Interaction: (interact) The effect that two or more things have on each other.
**Transportation:** (transport) The process of moving objects from one place to another.

**Observation:** (observe) The act or process of carefully watching someone or something.

(Note: The word absorb is often confused with observe. Therefore both the word observe and absorb are included in the vocabulary list.)

**Materials:**
- Sand
- Iron Filings
- Salt
- 1 Funnel
- Filter Paper
- 2 pieces of Chromatography Paper per group of students
  - Coffee Filters can be substituted if needed.
- Food Coloring
- 1 Small Plastic Plate (or cup) per group of students
- Toothpicks
- Stapler
- Ballpoint Pens/Pencils for labeling
- 3 sets of 5 Black Felt Pens (Faber-Castell, Stylist, Express, Papermate…)
- White or light colored flowers – optional (carnations, daises, mums…)

**Activity 1: An Impossible Separation?**

**Mixture of Sand and Iron Filings:** Hand the students a small plastic cup that is filled with a mixture of iron filings and sand. Do not tell the students what the mixture is. Ask them to make some observations about the mixture: How many different types of grains make up the mixture? What are the colors? Can they make some guesses about what the substances might be? Give them a second cup and ask them to separate the two types of grains. (Students will think this is a ridiculous request because it is too difficult.) Tell them you have a tool that will help separate the two substances. Can they guess what it is? Hand out a magnet to each group then have them use the magnet to separate out the filings from the sand. What is different about the filings that make them to stick to the magnet? (They are magnetic.) Note: Wrapping the magnet in a paper towel first will make it easier to remove the filings from the magnet.

**Mixture of Sand and Salt:** As a follow up activity make a mixture of sand and salt. Have students figure out a way to separate the sand and salt. Demonstrate the separation into a beaker or cup using coffee filter paper to filter off the sand. Leave the beaker or cup containing salt water on a window sill to evaporate the water. You can leave the beaker for the rest of the week to see how much it evaporates.
Activity 2: Separating Food Coloring

Separating two substances that have different physical properties can sometimes be a fairly simple task. For instance, a mixture of sand and salt can easily be separated by adding water to dissolve the salt, filtering the mixture to remove the sand, and evaporating the water to recover the salt. But what if the substances to be separated have similar physical and chemical properties? The answer is chromatography. The colors in ink and food dyes are chemical substances made up of carbon, hydrogen, nitrogen, oxygen, sulfur, and sodium atoms bound together in various ways to give different colors. The structures of a few common food dyes are shown below.

FD&C Blue No. 1

FD&C Yellow No. 5

FD&C Red No. 40

Paper is made up of cellulose - strong fibers consisting of carbon, hydrogen and oxygen atoms.

In paper, these cellulose fibers come together to form long thin chains. When paper absorbs water, tiny drops of water are drawn into the spaces in between the fiber chains by a process called “capillary action.” Capillary action is the ability of a substance to draw another substance into it. For example, plants and porous paper both absorb water. Capillary action is a physical effect caused by the interactions of a liquid with the walls of a thin tube (otherwise known as a capillary). Water is a highly polar molecule, as is cellulose, so there is a strong attraction between water molecules and cellulose molecules. Water molecules are also strongly attracted to each other so as one water molecule moves closer to a cellulose molecule, the other water molecules follow. Capillary action is limited by the force of gravity and by the size of the tube – the thinner the tube, the higher the water will climb. This process is how even extremely tall trees such as redwoods can get water all the way up to their top leaves. Their trunks are made up of millions of tiny tubes called xylem, which are made of cellulose. (There is an optional activity at the end to demonstrate capillary action in plants.)
In this activity we are using the capillary action of water to move a sample solution of food dye or ink up through a piece of paper in order to separate each sample into its component colors. As the water moves up, the component colors are separated as follows:

1. The water moves up the paper until it meets the sample spots, which are then dissolved by the water.
2. The atoms in the colors of dye or ink interact with the atoms of the cellulose and water.
3. Because the different colors have different chemical structures, their interactions with the cellulose and with the water will be different.
4. The stronger the interaction between a specific color and cellulose, the SLOWER that color moves. The stronger the interaction between a specific color and water, the FASTER that color moves.

Questions:
1. How can we separate a mixture of sand and salt?
2. How does a paper towel absorb water?
3. How does a mixture of colors separate into its component colors?

The teacher should go over orally how to use the words in the question to answer the question:
We can separate a mixture of sand and salt by ____________________________
A paper towel absorbs water by capillary action, which is________________

Procedure:
1. On a piece of filter paper, write your name in the upper right hand corner using a ballpoint pen or pencil – not a felt pen.
2. Put four different food colors in four small plastic cups, in a fifth mix all four food colors. Put a toothpick in each container.
3. Using the toothpick, put a small dot of each color 1 inch from the bottom of the filter paper. Near each dot identify the color using a ballpoint pen or pencil: R, B, Y, G, Mix (This step can be accomplished with minimal mess and chaos by setting up one or two “dotting” stations and having students line up to dot their papers assembly line style.)
4. Form the paper into a cylinder and staple the edges together, leaving a small gap so that the EDGES DO NOT MEET.
5. Put enough water on a plastic plate to just cover the bottom. This water is called the solvent and it is used to separate the different colors in the dyes.
6. Put the paper cylinder on the plate, placing the colored spots at the bottom. The dots of color should not touch the water!! (If using a plastic cup make sure that the paper does not touch the wall of the cup.)
7. Allow the solvent to rise up the filter paper to within about 2-3 cm from the top.
8. Watch the solvent rise and note how the dots begin to separate into bands of color as they are move along. This is your chromatogram.
Activity 3: Solving a Mystery with Science
Which Pen Wrote the Ransom Note? (Separating Colors in Inks)

In this activity water is the solvent and black ink is the test substance. The ink that your students test will separate into bands of brightly colored pigments.

Procedure:
1. Decide on a story or mystery for why a ransom note was written. A convenient option is to read “The Fallbrook Mystery” included with this lesson plan. Have students read the story out loud.
2. Choose a pen to be the mystery pen and put a black dot on each piece of filter paper (see the “before” picture).
3. Distribute the pieces of filter paper with the mystery black dot and have students label this dot “mystery.” Tell the students that this is ink from the pen that wrote a ransom note and they must act as detectives to discover which black felt pen wrote the note.
4. Provide each group of students with five different black felt pens labeled 1, 2, 3, 4, 5, one of which is the pen that wrote the note, and challenge students to use chromatography to discover which pen wrote the note. (If using “The Fallbrook Mystery” the suspects have initials A, B, C, D, and E and these should be used instead of numbers.)
5. Students should prepare the filter paper as before, putting a dot of ink about 1 inch from the bottom of the paper next to the mystery dot already on the paper. Remember to label each dot 1, 2, 3, 4, 5 or A, B, C, D, E.
6. Repeat steps 4-7 from the previous activity.
7. Have students remove the filter paper from the solvent and compare the chromatograms from pens 1, 2, 3, 4 and 5 to the one from the mystery pen. Which pen wrote the ransom note?

Be sure to test the chromatograms of your black felt pens before having students try this activity. Make sure the chromatograms are distinct enough to identify the mystery pen.

Questions:
1. Which ink contained the greatest number of different colors?
2. How many different in patterns (chromatograms) were there?
3. Which ink traveled the farthest?
4. Why do some colors travel more quickly up the paper?
5. Why do some colors not travel very far?
6. Which colors were strongly attracted to the solvent? How do you know?

I can infer that the colors __________ and ____________ were the most attracted to the solvent because they traveled the farthest.
**Additional (Optional) Activity: Capillary Action in Plants**

The effects of capillary action can be demonstrated using food coloring and white or light colored flowers. Flowers use capillary action to transport water and other nutrients even after they have been separated from the rest of the plant. This is why flowers in a vase with water can stay fresh after being cut. If food coloring is added to the flower’s water supply then the transport can be observed.

**Procedure:**

1. Fill a container with water and add enough food coloring to get the desired color. Around 5 drops per half cup of water should be sufficient.
2. Cut the stem of a flower and insert it into the container of colored water.
3. Observe the flower throughout the day, the color should travel up the stem and color the flowers. This may take anywhere from several hours to overnight.

Optionally, the stem can be split and each end inserted into a different color to create a multi colored flower. One side of the flower is one color while the other side is the other color. Have students explain why the colors do not mix.
The Fallbrook Mystery

By Megan Grabenauer

The city of Fallbrook has gone all awry,
pay close attention and I’ll tell you why.

Someone has stolen the town’s precious bell,
the one that hangs over the old wishing well.

With no bell to toll, no wishes come true,
and thus the town’s mood, is decidedly blue.

Not all the townsfolk are unhappy or sad,
in fact there are five that just might be glad.

Notes to the mayor they wrote each in black ink,
read them yourselves and see what you think:

It rings all day dawn until dark
Disturbing my home by the park
If it disappears
I shall shed no tears
Sincerely
- Amber the Aardvark

That bell as it rings through the air
Wakes me in my cave over there
I must hibernate
Before it’s too late
Make it stop!
- Billy the Bear

I loathe that bell as you well know
I’d be happy to see that thing go
Into the night
Quietly out of sight
There’s a thought!
- Cassy the Crow

I went walking with Diane the Doe
Sparks between us beginning to grow
But then the bell blared
And she ran away scared
Now I’m lonely
- Derrick the Dingo

I wish to fly like the other birds do
The bell tolls and yet nothing is new
I still run around
Firmly on the ground
The bell lies!
- Erin the Emu

At the scene of the crime, police found a note,
demanding a kite, and a new winter coat.

Whose pen wrote the note – to whom goes the blame?
The inks are all black, but are they the same?
Chromatography Worksheet

Name: __________________     Date: __________________

**Activity 1: An Impossible Separation?**

1. What two substances made up the mixture you first received?
   ______________________________________________________

2. How did you separate the two substances?
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

3. What is different about the two substances that allowed you to separate them?
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

**Activity 2: Separating Food Coloring**

4. What happened to the food coloring spots after you put your paper in the cup containing water?
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

5. Did any of the pure food colors contain more than one color? If so which one(s) and what colors did they contain?
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

6. What happened to the spot that was a mixture of all the food colors?
   ______________________________________________________
   ______________________________________________________
7. Overall, which color(s) moved up the most? Which stayed closer to the bottom of the paper? Why do you think some colors travel farther than others?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

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__________________________________________________________________________


**Activity 3: Solving a Mystery with Science**

8. What happened to the ink spots from the pens after putting your paper in the cup containing water?

__________________________________________________________________________

__________________________________________________________________________


9. Which pen was used to write the ransom note?

__________________________________________________________________________


10. How did you figure this out?

__________________________________________________________________________

__________________________________________________________________________

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__________________________________________________________________________
Word Analysis (Teacher Information)

Absorb (absorption): To take up by capillary action or chemical action. A liquid or solid material can absorb particles of gas or liquid. For example, a sponge absorbs water.

Attraction: (attract) The ability to make things move toward each other.

Chromatogram: The visual pattern formed by substances that have been separated by chromatography.

Chromatography: A technique used to separate mixtures into their individual components.

Interaction: (interact) The effect that two or more things have on each other.

Transportation: (transport) The process of moving things from one place to another.

Observation: (observe) The act or process of carefully watching someone or something.

<table>
<thead>
<tr>
<th>Prefix – (meaning)</th>
<th>Base/Root – (meaning)</th>
<th>Suffix – (part of speech)</th>
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</thead>
<tbody>
<tr>
<td>ab + (away from, off)</td>
<td>_____sorb (draw into)</td>
<td>+ tion (noun)</td>
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<tr>
<td>a + (toward)</td>
<td>+ tract (to pull)</td>
<td>+ tion (noun)</td>
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<td>chroma + (color)</td>
<td>_____gram (something written or drawn, a record of)</td>
<td>+ y (noun meaning ‘study of’)</td>
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<td></td>
<td>_____graph (something written or drawn)</td>
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<td>inter + (between)</td>
<td>_____act _____ (to behave in a particular way)</td>
<td>+ tion (noun)</td>
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<td>trans + (across)</td>
<td>_____port _____ (carry)</td>
<td>+ tion (noun) + er (noun person)</td>
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<tr>
<td>ob + (toward)</td>
<td>_____serve _____ (keep, save)</td>
<td>+ tion (noun) + er (noun person)</td>
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</table>

Note: Observe and absorb are both included in this exercise because students often confuse them.

Online resources:
http://ueno.cool.ne.jp/let/prefix.html
http://www.southampton.liu.edu/academic/pau/course/webesl.htm
http://www.msu.edu/~defores1/gre/roots/gre_rts_afx1.htm
http://sps.k12.ar.us/massengale/prefix_suffix_list.htm
http://www.lausd.k12.ca.us/lausd/resources/verbal.clues.with.latin/latinmainmenu.html

Nancy Escamilla – 8/07
Word Analysis (Student Worksheet)

Place the word parts of the following words in the table below:

absorption  absorb  attraction  chromatogram  chromatography
interaction  transportation  transporter  observation  observer

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**Bingo Game Board**

(This should go in the Student Lab Notebook to be used to review vocabulary in a week or two)

- Students write the vocabulary words from their list in the boxes in any order they choose
- The teacher reads a definition
- Students use a chip to cover up the corresponding vocabulary word
- When a student claims to have “Bingo”, the student reads off the words and the teacher reviews the Bingo check list to see if the definitions for these words were given
- Students re-use their Bingo game board for vocabulary review
## Chemical and Physical Properties Word List

### Bingo Checklist

The teacher reads vocabulary words off the Bingo checklist out of order. Students play Bingo after they are familiar with the words. To help students learn and remember the vocabulary, do activities, demonstrations, or show images.

<table>
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<tr>
<th>1st game</th>
<th>2nd</th>
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Polarity of Water: Activities or Demonstrations

Jumping paper: To show the attractive force between water molecules.

Standards Addressed: Grade 4: 1e
Grade 5: 1b, 1g

Materials:
- Clear plastic cup filled half-way with water
- Newspaper

Procedure: Cut a thin, long strip of paper, 0.25” wide and 17” long or longer. Newspaper works well. Use the edge of a blade of a pair of scissors to curl the strip of paper and make a 90 degrees fold a ½ inch from the end. You can also fold the entire strip of paper accordion style. Fill a clear plastic cup half way with water. Soak the folded end of the strip in the cup of water. Take the strip out of the water. Slowly bring the wet end of the curled paper near the water and watch it “jump” towards the water. Gently pull it out of the water – you can see it hold on and then release with a jump. Ask students to explain this observation. Water is strongly attracted to itself. Why? Water is a polar molecule. It has a net negative charge on the oxygen and a net positive charge on the hydrogen.

![Image of water molecule]

The oxygen atoms of water molecules are attracted to hydrogen atoms of other water molecules because negative and positive charges attract.

Bending Water: Static electricity can be a problem when the humidity is low. It causes shocks and makes dust stick to surfaces, and it can literally make your hair stand on end. In this experiment, you will see that it also can move things around. This experiment will not work if the humidity is high.

Materials:
- a nylon comb or a balloon
- a water faucet
**Procedure:** Adjust the faucet to produce a small stream of water. The stream should be about 1.5 millimeters (1/16 inch) in diameter.

Run the comb through your hair several times. Slowly bring the teeth of the comb near the stream of water, about 8 to 10 centimeters (3 or 4 inches) below the faucet. When the teeth of the comb are about an inch or less away from the stream, the stream will bend toward the comb.

Move the comb closer to the stream. How does the distance between the stream and the comb affect how much the stream bends? Run the comb through your hair several more times. Does the comb bend the stream more now?

Change the size of the stream by adjusting the faucet. Does the size of the stream affect how much the stream bends?

If you have other combs, you can try these to see if some bend the stream more than others. Or you can use a balloon. Rub the balloon on a piece of clothing to build up charge on the balloon.

**Static electricity** is the accumulation of an electrical charge in an object. The electrical charge develops when two objects are rubbed against one another. When the objects are rubbed together, some electrons (charged components of atoms) jump from one object to the other. The object that loses the electrons becomes positively charged, while the object that they jump to becomes negatively charged. The nature of the objects has a large effect on how many electrons move. This determines how large an electrical charge accumulates in the objects. Hair and nylon are particularly good at acquiring charge when they are rubbed together.

**Attraction between Opposite Charges (+/-):** A charged object attracts small particles, such as dust. The charge in the object causes a complementary charge to develop in something close to it. The complementary charge is attracted to the charged object. If the complementary charge forms on something tiny, such as dust particles, these tiny particles move to the charged object. This is why your television screen becomes dusty faster than the television cabinet. When a television operates, electrons fly from the back to the screen. These electrons cause the screen to become charged. The charge on the screen attracts dust.

The comb attracts the stream of water in the same way. The charge on the comb attracts the molecules of water in the stream. Because the molecules in the stream can be moved easily, the stream bends toward the comb.

When you comb your hair with a nylon comb, both the comb and your hair become charged. The comb and your hair acquire opposite charges. Because the individual hairs acquire the same charge, they repel each other. Perhaps you noticed that after running the nylon comb through your hair, the hairs on your head stood on end. This is a result of your hairs repelling each other because they are charged.

**Humidity:** Static electricity is more of a problem when humidity is low. When humidity is high, most surfaces are coated with a thin film of water. When objects coated by a film of water are rubbed together, the water prevents electrons from jumping between the objects.

**Reference:** Chemical Demonstrations, A Handbook for Teachers in Chemistry by Bassam Z. Shakashiri, VOL. 3, Page 329
http://scifun.chem.wisc.edu/HOMEEXPTS/BENDWATER.html