

## Paper Chromatography

### Summary

This experiment shows how ink can be separated into its component dyes by chromatography. This is an illustration of an important technique used in all chemical sciences.

### Materials

Coffee filter (use a brand which is fairly thick, such as the Molinex or the Kafilta cone filter), plastic cups, water, rubbing alcohol, one each of several brands of black felt tip pen or marker (use no more than one brand of "permanent" marker, the rest should be the non-permanent type)

### Procedure

1. Put a small amount of water in a plastic cup, so as to barely cover the bottom of the cup.
2. Assign a number to each pen.
3. Cut the coffee filter into long strips (about 3 - 4 cm wide and 10 cm long). Cut it in such a way that the grain of the filter paper runs parallel to the 10 cm dimension of the strip. Fold each strip along the 10 cm dimension so as to make a crease along the middle of the strip. Identify each strip near one end of the filter paper along the 10 cm dimension. For convenience, this end will be called the top of the paper. Use the same numbering system as used with the pens.
4. Take a black pen and a strip. The two should have the same identification number. Make two small marks with the pen about 2 cm from the bottom of the strip, one on each side of the crease. (It is important to keep the size of the marks small). Repeat with another pen and another numbered strip until all the different pens have been used.
5. Take a marked strip and stand it in the cup so that the bottom of the strip is touching the water. Make sure that the pen mark stays above the water level.
6. Observe the separation of the ink into different colors as water rises up the coffee filter. Remove the paper from the cup when the water (not the colors) has risen to about 2 - 3 cm from the top.
7. Repeat the above with all the marked strips. Observe the color patterns produced with different pens.
8. Repeat the above using rubbing alcohol in the cup instead of water. Compare the color patterns produced in this case with those produced with the corresponding pens using water.

### Tips:

1. Coffee filter is recommended for this experiment because it is cheap and can be purchased easily. The experiment works even better with filter paper or chromatography paper, but these are more expensive. Black pens are recommended because they usually have many different dyes in their ink. Students should be encouraged to try markers of different colors or food coloring (the green food coloring works well). Do not be disappointed if the marker does not produce a dramatic separation pattern.
2. Water rises up the coffee filter because of a phenomenon called capillary action. It is the same action which a tree uses to soak water up its trunk and its branches. After all, coffee filter is made from trees! One can mimic a tree using a thick paper towel and rolling it as a trunk.
3. The role of the water and the rubbing alcohol in this experiment is that of a carrying liquid, because these liquids carry the ink up the coffee filter. The technical term for this is an eluant.
4. Students are expected to make the following observations:
  - a. marks made from the same pen always produce the same separation pattern, i.e., the different colors are in the same order after the separation. The size of the original dot on the paper has no effect on the separation pattern, although the separation is better defined if the dot is smaller.
  - b. different brands of pen produce different separation patterns.
  - c. different carrying liquids produce different separation patterns with the same pen.

5. Students should be shown that different pens from the same batch (same brand and same model) produce the same separation pattern.
6. The separation patterns produced by different brands of pen and different carrying liquids are governed by several factors:
  - a. The composition of the ink. Different companies use different dyes to make their ink. Some are doing it to produce special physical or visual effects, some are doing it so they cannot be accused of copying other people's product.
  - b. The solubility of each component dye in the carrying liquid. If the dye is not soluble in the carrying liquid, it cannot be carried up the paper. This is the case of the permanent ink with water as the carrying liquid. Since the permanent ink is not soluble in water (hence the term : "permanent"), the mark stays in the starting place. Since most permanent ink are soluble somewhat in organic solvents, one can get it to produce a pattern using rubbing alcohol as the carrying liquid.

Typically, the most soluble dye will move up the paper the most and the least soluble dye will move up the least. If a dye is very soluble in the carrying liquid, it will follow the top of the water level up the paper closely. Try the experiment with a washable marker.

- c. The extent to which the ink clings to the paper. A dye which is strongly attached to the paper will not move up the paper much.
  - d. The length of the paper. The separation of the different dyes along the paper increases if the carrying liquid is allowed to carry the ink up a longer distance. At the beginning of the experiment, the colors are still bundled together. As the carrying liquid moves up the paper, the separation becomes more and more complete. Note, however, that the order of the colors does not change with the distance traveled.
7. The teacher can take one of the markers which the students have used and use it to put a mark on a coffee filter. Give this to the students as an unknown and ask the students to identify which marker was used to make the mark. The students should be able to devise the following procedure:
  - a. Take the paper with the unknown and run the paper chromatography experiment in exactly the same way as with the other markers.
  - b. Observe the separation pattern produced by the unknown, and compare it with the patterns produced by the known markers.
  - c. The marker which produces the same pattern as the unknown is the origin of the unknown.
  - d. To obtain a better confirmation, you can perform a chromatography of the unknown and of one (or many) known marker, simultaneously, on the same paper.

These types of approach and reasoning are very similar to those used in a very important branch of chemistry called analytical chemistry, which is the science of finding out the composition of unknown substances. Chromatography is an important tool in analytical chemistry. For example, this can be used to identify the author of a crime.

8. There are many different types of chromatography besides the paper chromatography illustrated in this experiment. Instead of paper, different minerals and synthetic compounds have been used to improve the separation of different components in a mixture. Chromatography can also be used to separate different components in a gas mixture
9. Because of its ability to separate different components in a mixture, chromatography is also used to purify chemicals.

## References

Similar forms this experiment have been reported in many books, for example, in Exploring Chemistry, vol 1, Canadian Society for Chemistry (1996), Discovering Chemistry, Canadian Society for Chemistry (1993), or in Chemical Activities, by C.L. Borgford and L.R. Summerlin, American Chemical Society, Washington, (1988). The experiment has been modified by different National Chemistry Week coordinators in the past to illustrate different aspects of this technique.