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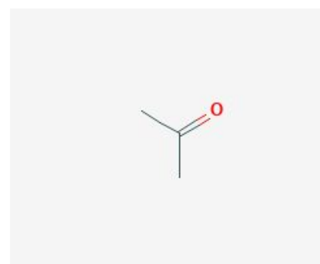
Chemistry Investigation

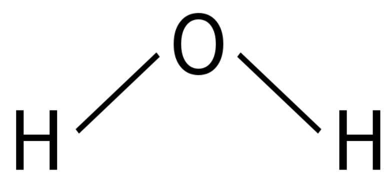
Research question : What is the effect of acetone on paper chromatography?

Investigating the polarity of solvents conventionally used in paper chromatography

Introduction :

Chemistry classrooms throughout the United States use different methods of chromatography (thin-layer, liquid, paper, etc.) to separate both liquids and solids. The uses of chromatography are endless- it can be used to find the mysterious pen thief or discerning the ingredients in a spinach solution. However, paper chromatography especially is not always easy to decipher and usually see yields with very low resolution. Ideally, all the ingredients in the test substance would separate; therefore making the identification of these substances much easier. In experimentation, the colors in an ink pen may separate, but the resolution is not clear. I am curious to see if there is a way to yield better results in paper chromatography.[1]





Paper chromatography requires finding a solvent that will dissolve the pigment being tested. In this way, water a possible polar solvent; however, it has been seen in other experiments to have unfavorable outcomes. Fully nonpolar solvents like mineral oil would be better for polar substances. The solvent must travel up the chromatogram to allow the pigment to separate. The further up the paper a solvent can travel, the greater amount of resolution will result. Because acetone is an amphipathic, it can theoretically dissolve both polar and nonpolar substances with a greater resolution. Acetone has a significant partial negative charge on the oxygen atoms, a slight positive charge on the carbonyl carbon, and two nonpolar alpha-carbons whereas water does not. While acetone has large dipole moments and contain bond between atoms with different electronegativities, nonpolar solvents like water contain bonds between atoms with similar electronegativities like carbon and hydrogen.

Hypothesis :

Theoretically, because acetone is amphipathic, it will yield a higher resolution than a water solvent in a paper chromatography experiment. An experiment by Charlotte Brown, a graduate of the School of Criminology and research assistant Paul L. Kirk conducted a research for scientific criminal investigation. The study found that the best solvent tested was t-butanol:water:acetone:hydrochloric acid(conc) with a ratio of 10:20:10:1. The study concluded

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[1] Northwestern University Pritzker School of Law

that "acetone water mixtures produced separations that were definite but with very high R_f values that showed small differences only". [2]

Variables :

Independent	*Type of solvent/solvent mixture* - The chromatograms were placed separately into solutions of 10 ml of solely water, solely acetone, and a mixture of acetone-water.
Dependent	*R_f value of dye separation* - R_f values were taken for each color dye separated on the chromatogram.

Controlled	Method of control	Possible effect on results
Time spent in solvent	Each chromatogram was kept in the solvent for 50 minutes.	The R_f value may change depending on how long the chromatogram is kept in the solvent. In theory, the longer the pen ink is kept in the solvent, the better the resolution will become.
Pen ink source	To ensure that the R_f values being compared had the same chemical composition, the same pen was used for all tests (expect during a side test in determining which pen would work at all).	Pens of different color and different brands are made with different formulas and will result in different qualitative and quantitative data.
Volume of solvent in erlenmeyer flask - 10 mL	Using a 10 mL graduated cylinder, 10 mL of solution was measured for each solvent/solvent mixture.	Changing the volume of the solvent may change the distance traveled by the solvent in the fixed amount of time; therefore, the R_f value would be affected.
Type of chromatography paper	This experiment calls chromatography paper specifically.	Different types of paper will yield different results. For example, printer paper is coated so the solvent will not easily be absorbed by capillary

[2] Brown, Charlotte

		action.[3]

Apparatus :

- Chromatography paper
- 250 Erlenmeyer flask
- 10 mL graduated cylinder
- 57.5 mL of water
- 31.5 mL of Acetone
- No. 2 pencil
- ruler

Risk Assessment :

Acetone can cause irritation to the skin as well as eye irritation. To prevent injury, wear eye protection; however, gloves are not necessary for 10 mL of acetone at a time.[4]

Experimental Procedure :

Experimental Procedure 1: Testing which pen will have best yields for Experimental Procedure 2

1. Take a piece of chromatography paper and draw a pencil line 2 cm from the bottom edge of the paper (acts as the origin)
2. Put a small dot on the line with the tested pen.
3. Take an erlenmeyer flask and add 10 mL of water.
4. Put strip of chromatography paper with pen dot in solvent.
5. Let the water run up the paper for 50 minutes.
6. Take out paper and measure R_f value.
7. Repeat steps 1-6 for other pens.

*Pens can be tested at the same time in different flasks to save time.

Experimental Procedure 2: Paper Chromatography with Acetone

1. Measure out 10.0 mL of acetone using the graduated cylinder and pour into erlenmeyer flask.
2. Take a 15 cm piece of chromatography paper and draw a pencil line 2 cm from the bottom edge of the paper
3. Draw a small dot on the line with the pen that worked best in Experimental Procedure 1.
4. Put strip of chromatography paper with pen dot in solvent.
5. Let the acetone run up the paper for 50 minutes.
6. Take out paper and measure distance traveled by solvent and distance traveled by solute.

[3] *PAPER CHROMATOGRAPHY*, 1997, genchem.rutgers.edu/chrompap.html.
[4] *UCSB Science Line*, scienceline.ucsb.edu/getkey.php?key=4198.

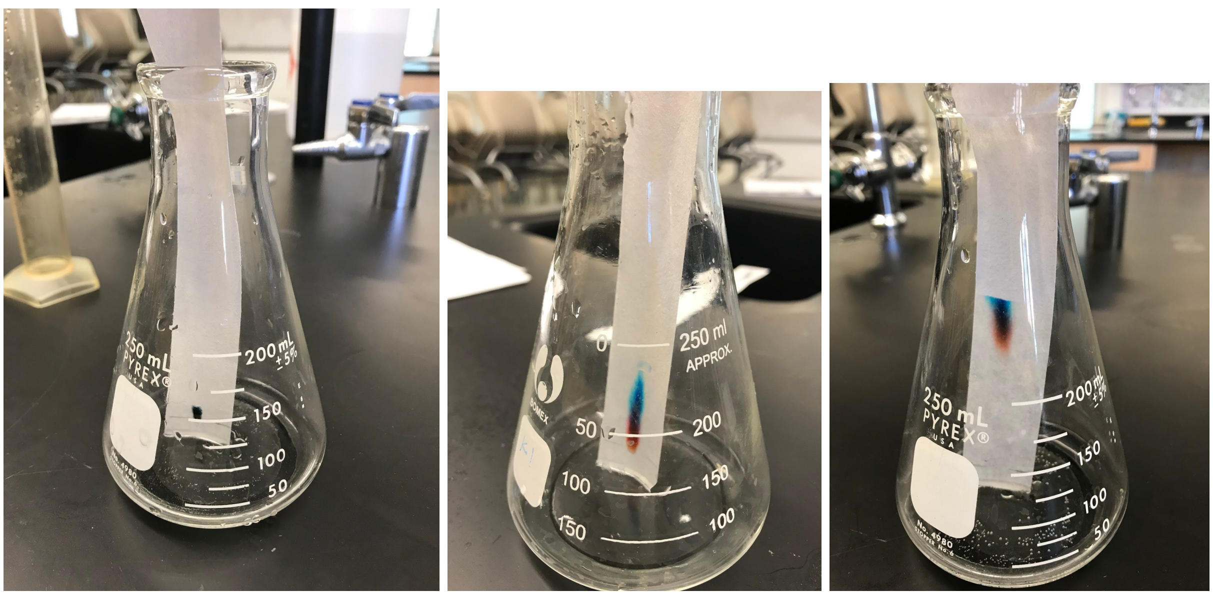
7. Mix 5.0 mL of acetone with 5 mL of water in graduated cylinder.
8. Repeat steps 2-6 for this mixture.
9. Mix 7.5 mL of acetone with 2.5 mL of water in graduated cylinder.
10. Repeat steps 2-6 for this mixture.
11. Mix 9.0 mL of acetone with 1.0 mL of water in graduated cylinder.
12. Repeat steps 2-6 for this mixture.

Calculation Method :
The retention value (R_f value) is used to determine how polar a solute is. A solute (in this case, the pen ink components) with a high R_f value would be less polar and more attracted to the mobile phase while solutes with a low R_f value would be the opposite- more polar and more attracted to the stationary phase. The R_f value can be determined by the equation below:

$$R_f \text{ value} = \frac{\textit{Distance traveled by solute}}{\textit{Distance traveled by solvent}}$$

Diagrams :

Photographs 1, 2, &3 - Set up and time stamps of phases of black brush pen in 75% Acetone to 25% Water solvent solution



Results :

Photographs 4 & 5 - Set up and results of paper chromatography to measure R_f value

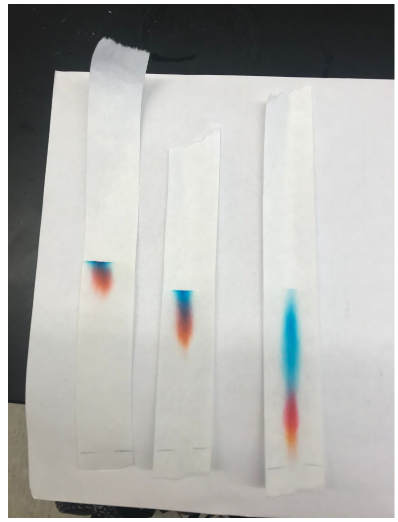


Table 1 - Raw quantitative data showing distance traveled by ink components in water solvent
* This data is a side test to figure out which pen would work best to later test only that pen for the acetone solvent.

<table>
<tr><th>Pen Type</th><th>Distance traveled by components of pen ink (cm)</th></tr>
<tr><td>Uni-Ball Signo pen (black)</td><td>0 cm</td></tr>
<tr><td>Paper Mate Profile pen (black)</td><td>0 cm</td></tr>
<tr><td>Art 101 brush pen (black)</td><td><table><tr><td>Blue</td><td>8.5 cm</td></tr><tr><td>Purple</td><td>8.0 cm</td></tr><tr><td>Orange</td><td>7.5 cm</td></tr></table></td></tr>
<tr><td>Art 101 brush pen (pink)</td><td><table><tr><td>Pink</td><td>3.0 cm</td></tr></table></td></tr>
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Table 2 - Processed quantitative data showing the R_f values of ink components in water solvent

Pen Type	**R_f value**
Uni-Ball Signo pen (black)	0.00

Paper Mate Profile pen (black)	0.00	
Art 101 brush pen (black)	Blue	0.976
	Purple	0.941
	Orange	0.882
Art 101 brush pen (pink)	Pink	0.577

Qualitative Data : The Uni-ball Signo and Paper Mate Profile pens did not yield any separation nor were they mobile. However, both brush pens moved up the chromatogram with the Art 101 brush pen (black) separating into three distinct colors, blue, purple, and orange. Though the Art 101 brush pen in pink was mobile, it did not separate into different colors; therefore, the Art 101 brush pen in black was the best option for moving forward in testing.

Table 3 - Raw qualitative data showing distance traveled of ink components in mixed solutions of water and acetone

Solvent Mixture	**Distance traveled by components of pen ink (cm)**	
100% Acetone solvent	Blue	1.5 cm
50% Acetone - 50% Water	Blue	8.9 cm
	Purple	8.5 cm
	Orange	7.7 cm
75% Acetone - 25% Water		

	Blue	7.0 cm
	Purple	6.2 cm
	Orange	5.0 cm
90% Acetone - 10% Water	Blue	5.3 cm
	Pink	2.2 cm
	Orange	1.3 cm

Table 4 - Processed quantitative data showing R_f values of tested chromatograms in Acetone - Water mixture

Solvent Mixture	**R_f values of components of pen ink**	
100% Acetone solvent	Blue	0.156
50% Acetone - 50% Water	Blue	0.989
	Purple	0.944
	Orange	0.856
75% Acetone - 25% Water	Blue	0.959
	Purple	0.849
	Orange	0.685
90% Acetone - 10% Water	Blue	0.654
	Pink	0.272

	Orange / 0.160

Qualitative data : With 100% Acetone, there was little color change. The only color that separated was the color blue and it was not very attracted to the mobile phase. Because it was already determined that this Art 101 brush pen could separate into other colors, water was added to solution to better separate the pen ink. With 50% Acetone to water, some color separation occurred- blue, purple, and orange. This was the same observation with 75% Acetone to 25% water; however, the ink components were even more spread apart. With 90% Acetone to 10% water, the separation was even more clear. It is also pertinent to note that the purple color that was present in the 50% and 75% Acetone solutions completely separated into blue and pink for the 90% Acetone solution.

Data Processing :

Calculating percentage uncertainty = $\frac{Absolute\ uncertainty}{Measurement\ taken}$ x 100, with the uncertainty of a ruler being ±0.05 cm[5]. The table below calculates the total percent uncertainty when measuring the distance traveled by the solute and the solvent.

Solvent Mixture	**Distance traveled by components of pen ink (cm)** (±0.05 cm)	**Total percent uncertainty for distance traveled by components of pen ink**
100% Acetone solvent	Blue: 1.50 ± 0.05	Blue: 3.33%
50% Acetone - 50% Water	Blue: 8.90 ± 0.05 Purple: 8.50 ± 0.05	Blue: 0.56% Purple: 0.59%

5 *Measurement and Uncertainty*, www2.southeastern.edu/Academics/Faculty/rallain/plab194/error.html.

	Orange: 7.70 ± 0.05	Orange: 0.65%
75% Acetone - 25% Water	Blue: 7.00 ± 0.05 Purple: 6.20 ± 0.05 Orange: 5.00 ± 0.05	Blue: 0.71% Purple: 0.81% Orange: 1%
90% Acetone - 10% Water	Blue: 5.30 ± 0.05 Pink: 2.20 ± 0.05 Orange: 1.30 ± 0.05	Blue: 0.94% Pink: 2.27% Orange: 3.85%

Conclusion :

According to the data collected, acetone does have an effect on paper chromatography. The R_f values and qualitative data collected and depicted in Tables 1 and 2 shows that a high concentration of acetone mixed with water in solution gives the best separation amongst the ink colors of an Art 101 brush pen (black). Previous studies have found that a high concentration of acetone has yielded greater resolution in paper chromatography and this experiment supports this claim. Though acetone on its own does not move the ink up the chromatogram easily, adding water allows the ink to drag up the paper.

The results strongly support the initial hypothesis that adding acetone would develop definite separations; however, the R_f values were high.

Strengths and Weaknesses :

One strength in this experiment was that the data is reliable based on the calculated percent uncertainty which ranged from 0.56% to 3.85% uncertainty. However, there is a limitation of the data- more trials would have even better supported the investigation.

Another weakness in this experiment was the amount of time each chromatogram was in the solvent. In this experiment, the components of pen ink were only given 50 minutes to sit in the solvent; however, other previous studies like the investigation done by Charlotte Brown and Paul Kirk have left the chromatograms in for a few hours to even a day to fully separate. In this experiment, it is unknown how acetone would have affected the chromatogram if allowed to fully separate.

Future Procedures :

If this procedure was to be modified, one change that may benefit the results would be the change in how long the chromatogram was kept in the solvent. Because the R_f values were so high, it is speculated that the solvent could have traveled farther up the chromatogram, and the same could be said about the pen ink. However, if the solvent was left overnight or even a few more hours, the procedure would have to take into account evaporation of the solvent.

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