

Name _____

Microfluidic Droplets Lab

Pre-Lab Assignment

- This pre-lab assignment is worth 5 points.
- This part of the pre-lab assignment is due *at the beginning* of the lab period, and must be done individually *before you come to lab!*


I. Background Preparation

- **Read this experiment thoughtfully**

Mentally note any procedural questions and plan how you and your partner will complete all experiments efficiently during the three-hour lab period.

II. Safety Hazards/Precautions

1. Complete the following table. Refer to the Safety Data Sheets (SDS) provided by your instructor. You can also search for a SDS by typing in the chemical name into the search box on the Sigma-Aldrich website: <http://www.sigmaaldrich.com/united-states.html>. After selecting the correct material, click on the SDS link to view.

Materials	GHS Pictograms (Circle all that apply)	Hazard Statements (Check and list all that apply)
propylene glycol		<input type="checkbox"/> Corrosive <input type="checkbox"/> Toxic _____ <input type="checkbox"/> Flammable <input type="checkbox"/> Reactive _____ <input type="checkbox"/> Irritant _____ <input type="checkbox"/> Other? _____
Waste Disposal	Identify (briefly) how you will dispose of waste materials from this experiment.	

2. **Workplace/Personal Cleanup Notes** (indicate what you will do to clean up yourself and your lab space before you leave the lab):



IV. Vocabulary

Define the following:

- Chemotaxis:
- Concentration:
- Evaporation:
- Fluid:
- Hydrophilic:
- Hydrophobic:
- Intermolecular force:
- Microfluidic:
- Polar molecule:
- Solution::
- Surface tension:



Learning Objectives

- Understand how the polarity of a substance affects its physical properties of boiling point and surface tension.
- Test how the concentrations of liquids in two-component solutions affect the interaction of individual solution droplets.
- Explain how molecular shape and polarity of individual particles.
- Understand how differences in substances in a two-component solution affect the interaction of the microfluidic droplets.
- Understand how the movement of two-component solutions is used to in the development of microfluidic devices.

Introduction

A droplet of water that falls on a leaf, a spider web, or a window is a simple phenomenon. Water is a polar molecule composed of one oxygen and two hydrogen atoms. A water droplets unique shape results from the cohesion, adhesion and surface tension of these polar molecules.

Cohesion is the attraction of water molecules to water molecules. Adhesion is water molecules attraction to other polar or hydrophilic molecules. Surface tension is the pulling of surface water molecules to the center of the droplet by the cohesive force of internal water molecules. When water is mixed with other substances, the nature of the molecules in a droplet undergoes complex and dynamic changes. This lab, explores the dynamic interactions of a two-component solution as an inquiry into very simple microfluidic droplets.

Applications: Microfluidics is the science of designing, manufacturing, and formulating devices and processes in micro-channel networks for the purpose of microscale analytical chemistry and electronics. Microfluidics emerged in the beginning of the 1980s and is used in the development of inkjet print heads, DNA chips, lab-on-a-chip technology, micro-propulsion, and micro-thermal technologies.

Materials

- 24-well plate with propylene glycol and food coloring
- 20 μL and 200 μL micropipettes or similar micro-thin stem pipets
- Beaker of water
- Micropipette tips
- Microscope slides
- Black sharpie
- Glass beakers or ceramic plates
- Bunsen burner
- Tweezer
- Ruler
- White paper
- Stopwatch/Timer (for optional extension only)



Experimental Procedure

(i) Observation of Microfluidic Droplets

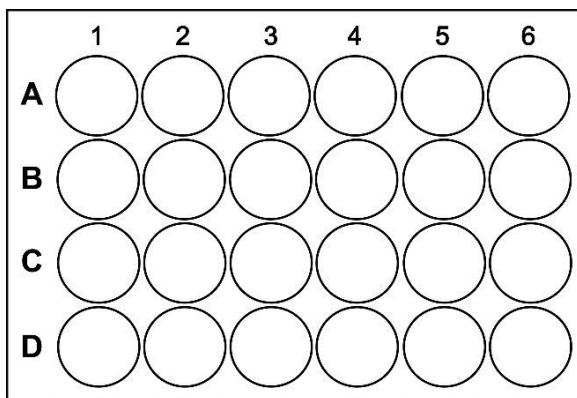
Water droplets that fall on a leaf, a spider web, or a window are simple phenomenon. This lab explores the droplets of food coloring as a very simple inquiry into microfluidic droplets.

1. Clean a slide by holding a microscope slide in a flame for 20 seconds.
2. Place the slide on a beaker "flame side up" to cool.
3. Randomly place 3 μL drops of each color on the slide. *Do not exceed 5 drops of each color.*
4. Observe and record the behavior of the drops of liquid.

(ii) Investigating the Effect of Propylene Glycol Concentration Microfluidic Droplets

Food coloring is a two-component solution composed of propylene glycol and water. This lab explores how changes in the concentrations of propylene glycol affects the motion of the microfluidic droplets.

1. Prepare a dilution curve of each dye using the 24-well plate.
 - a. Place 20 μL propylene glycol in Wells B2, then add 380 μL of blue food coloring to Well B2.
 - b. Place 40 μL propylene glycol in Wells B3, then add 360 μL of blue food coloring to Well B3.
 - c. Place 60 μL propylene glycol in Wells B4, then add 340 μL of blue food coloring to Well B4.
 - d. Place 80 μL propylene glycol in Wells B5, then add 320 μL of blue food coloring to Well B5.
 - e. Place 100 μL propylene glycol in Wells B6, then add 300 μL of blue food coloring to Well B6.
 - f. Repeat Steps a-e using the red food coloring in Row C.
 - g. Repeat Steps a-e using the green food coloring in Row D (optional).



<http://www.cellsignet.com/media/plates/24.jpg>



2. Prepare a glass slide
 - a. Clean a slide by holding a microscope slide in a flame for 20 seconds.
 - b. Place the slide on a beaker "flame side up" to cool.
 - c. Using the black sharpie, divide the slide into six equal sections. Label each section.

B1	B1	B1	B1	B1	B1
C1	C2	C3	C4	C5	C6

3. Place 3 μL drops of the solution in Well B1 to the top of each section.

B1 ●	B1 ●	B1 ●	B1 ●	B1 ●	B1 ●
C1	C2	C3	C4	C5	C6

4. Place 3 μL drops of solution in Well C1 to the bottom of the first square. Observe and record the droplet movement and behavior.

B1 ●	B1 ●	B1 ●	B1 ●	B1 ●	B1 ●
C1 ●	C2	C3	C4	C5	C6

5. Place 3 μL drops of the solution in Well C2 to the bottom of the next square. Observe and record the droplet movement and behavior.

B1 ●	B1 ●	B1 ●	B1 ●	B1 ●	B1 ●
C1 ●	C2 ●	C3	C4	C5	C6

6. Place 3 μL drops of the solution in Well C3 to the bottom of the next square. Observe and record the droplet movement and behavior.

B1 ●	B1 ●	B1 ●	B1 ●	B1 ●	B1 ●
C1 ●	C2 ●	C3 ●	C4	C5	C6



7. Place 3 μL drops of the solution in Well C4 to the bottom of the next square. Observe and record the droplet movement and behavior.

B1	B1	B1	B1	B1	B1
C1	C2	C3	C4	C5	C6

8. Place 3 μL drops of the solution in Well C5 to the bottom of the next square. Observe and record the droplet movement and behavior.

B1	B1	B1	B1	B1	B1
C1	C2	C3	C4	C5	C6

9. Place 3 μL drops of the solution in Well C6 to the bottom of the next square. Observe and record the droplet movement and behavior.

B1	B1	B1	B1	B1	B1
C1	C2	C3	C4	C5	C6

10. Repeat Steps 3 to 10 using the blue and green food coloring. Observe and record droplet movement and behavior carefully.

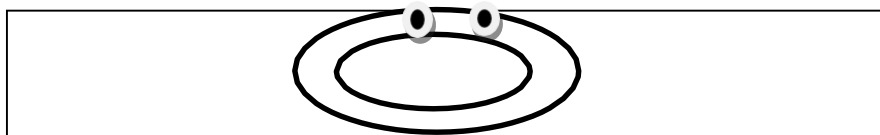
11. Clean the slides using the wash bottle. Throw away all used pipet tips.



4. Prepare your timer/stopwatch to time the response.
5. Place 3 μL of the 5% red food coloring 2 cm from the end of the slide.
6. Place 3 μL of the 10% green food coloring 1 cm from the end of the slide, then immediately press start on your timer/stopwatch.
7. Observe and record the time it take for the droplets to reach the end of the slide.

CHALLENGE: Using different concentrations of propylene glycol, what is the fastest rate of droplet movement?

8. Slide 2 - Using the black sharpie, draw two concentric circles approximately 0.5 cm apart.



9. Prepare your timer/stopwatch to time the response.
10. Place 3 μL of the 5 % red food coloring at the top of the circle.
11. Place 3 μL of the 10 % green food coloring 0.5 cm the first droplet, then immediately press start on your timer/stopwatch.
12. Observe and record the time it take for the droplets to complete the circle.

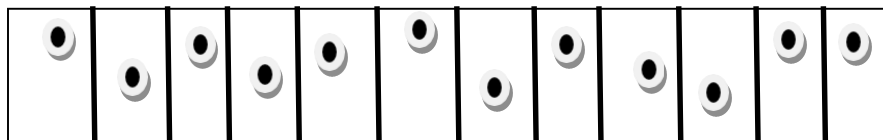
CHALLENGE: Using different concentrations of propylene glycol, what is the fastest rate of droplet movement?

Self –alignment – Long Range Interaction

1. Clean a slide by holding a microscope slide in a flame for 20 seconds.
2. Place the slide on a beaker "flame side up" to cool.



- Using the black sharpie, draw 10 lines vertically across the slide approximately 0.5 cm apart.



- Place 3 μL of the 25 % red food coloring at random points in each lane.
- Observe and record the droplets.

CHALLENGE: Does a different concentration of propylene glycol affect the rate at which the droplets align?

Self Assembly

- Clean a slide by holding a microscope slide in a flame for 20 seconds.
- Place the slide on a beaker "flame side up" to cool.
- Using the black sharpie, draw boxes as shown below (approximately 0.5 cm apart).



- Place 3 μL drops of decreasing concentrations of propylene glycol in each channel. Use different colors of food coloring to distinguish propylene glycol concentrations.
- Place the slide on an incline.
- Place 3 μL drops of most concentrated propylene glycol solution on the top line. Allow the droplet to move over the wells.
- Observe and record the wells it joins.
- Repeat again using another concentration of propylene glycol.

CHALLENGE: Can you extend the number of wells the droplet must pass over before joining a droplet? Evaluate additional concentrations of propylene glycol.



Reference Materials

Abate, T. *Stanford Researchers Solve the Mysteries of Dancing Droplets*. Stanford News. 2015. <http://news.stanford.edu/2015/03/11/dancing-droplets-prakash-031115/>

Cira, N. J.; Benusiglio, A; and Prakash, M. *Dancing droplets: Autonomous surface tension-driven droplet motion*. Phys. Fluids 26: 091113. 2014. <http://dx.doi.org/10.1063/1.4894407>

Cira, N. J.; Benusiglio, A; and Prakash, M. *Vapour-mediated sensing and motility in two- component droplets*. Nature 519, 446–450. 2015. <http://www.nature.com/nature/journal/v519/n7544/full/nature14272.html>

Cira, N. J.; Benusiglio, A; and Prakash. *You Can Reproduce The Awesome 'Dancing Droplets' Phenomenon At Home*. IO9, Gizmodo. 2015. <http://io9.gizmodo.com/you-can-reproduce-the-awesome-dancing-droplets-phenomen-1695523795>

Lewin, S. *2 Common Liquids Spontaneously Form Dancing Droplets*. Scientific American. 2015. <https://www.scientificamerican.com/article/2-common-liquids-spontaneously-form-dancing-droplets-video/>

Science Buddies. *Dancing Droplets*. Scientific American. 2015. <http://www.scientificamerican.com/article/dancing-droplets/>

Pettit, D. *Science of the Sphere Episode 1: Dancing Droplets*. Physics Central. 2012. <http://www.physicscentral.com/explore/sots/episode1.cfm>

Related Lessons

Frederick Balagadde: Bio-lab on a microchip. 2010, February. TED2010. http://www.ted.com/talks/frederick_balagadde_bio_lab_on_a_microchip.html

George Whitesides: Toward a science of simplicity. 2010, February. TED2010 http://www.ted.com/talks/george_whitesides_toward_a_science_of_simplicity

Freeman, S. *Properties of Water*. Biological Science. Pearson Prentice Hall, 2nd Edition. <http://www.sumanasinc.com/webcontent/animations/content/propertiesofwater/water.html>

Gordon, J.; Perpetua, S.; and Lindsay, R. *The Physics of Droplets*. ScienceTake. 2016. <http://www.nytimes.com/video/science/100000003584880/dancing-droplets.html>

Cool Droplet Videos

Bouncing droplets - High speed || MinuteLaboratory #17. 2013, July. Minute Lab. <https://www.youtube.com/watch?v=esC9Rg0SAA>

Selective droplet coalescence using microfluidic systems. 2012, April. Lab on a Chip. <https://www.youtube.com/watch?v=NwXiwNgNRXQ>



Acknowledgements

Seattle's Hub for Industry-driven Nanotechnology Education: www.seattlenano.org

North Seattle College: www.northseattle.edu

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This material is based upon work supported by the National Science Foundation under Grant Number 1204279. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.



(ii) Investigating the Effect of Propylene Glycol Concentration Microfluidic Droplets

Table 1: Effect of Propylene Glycol Concentration on Droplet Movement

Percent Propylene Glycol	Observations	
	Blue with Red	Blue with Green
	B1:C1	B1:D1
	B1:C2	B1:D2
	B1:C3	B1:D3
	B1:C4	B1:D4
	B1:C5	B1:D5
	B1:C6	B1:D6

Data Analysis

1. Calculate the percent of propylene glycol in each sample.

2. Which droplets merged?



Microfluidic Droplets Lab - Report Sheet

3. Which droplets chased another droplet?
4. Which droplet contains the highest concentration of water?
5. Is there a difference between the red and green food coloring?
6. What are some possible explanations for the movement of the colored droplets?

Discussion questions

1. Draw the Lewis structure of water and propylene glycol.
WATER:

PROPYLENE GLYCOL:

Which compound is more polar?



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2. What intermolecular forces exist between water and propylene glycol molecules?
3. Based on polarity, which molecule has the greatest surface tension?
4. How does surface tension affect the movement of a droplet?
5. Based on polarity, which molecule has the highest evaporation rate? Why?
6. In mixed droplets, how might the differences in evaporation rates affect molecules within a droplet?
7. How does the evaporation rate of water molecules in one droplet affect another droplet?

