Berkeley Engineers and Mentors

Crazy About Chromatography

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Field(s) of Interest: Chemistry, Biology, Engineering

Brief Overview:
In this lesson mentees will explore the concept of chromatography, and specifically how the unique properties of water make chromatography possible. Mentees will begin by exploring the unique properties of water, and how they relate to the intermolecular forces, then move onto how we can exploit these properties by performing different kinds of chromatography themselves.

Agenda:
- Introduction (5 min)
- Module 1: Hydrogen Bonding (10-15 min)
- Module 2: Capillary Action (10-15 min)
- Module 3: Chromatography (10-15 min)
- Conclusion (5 min)

Main Teaching Goals/Key Terms:
- ➔ **Hydrogen Bonding:** A specific type of intermolecular force, present in water, that only involves molecules containing hydrogen; this is the strongest intermolecular force
- ➔ **Capillary Action:** The action of water traveling up a small tube against gravity, due to strong adhesive forces
- ➔ **Chromatography:** The method of separation, where substances are separated via polarity as different substances move at different rates.

Background for Mentors

Module 1

- Hydrogen Bonding
- Surface Tension

Hydrogen bonding is one of the four types of intermolecular force, or secondary force, which is the force that exists *between molecules*. It is a special type of dipole-dipole attraction where a hydrogen atom bonds with one of the three atoms that are strongly electronegative: Fluorine, Oxygen or Nitrogen. Hydrogen bonding is also the *strongest* intermolecular force.

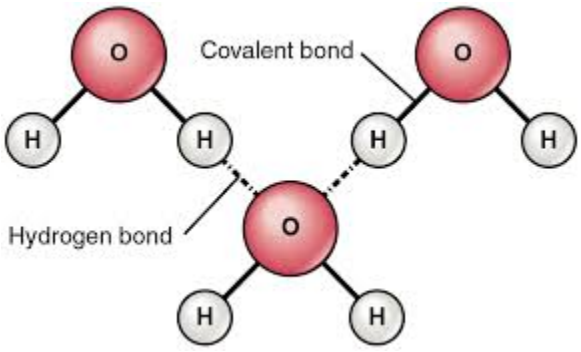


Figure 1: A picture that shows water molecules with the covalent bond that exist inside each molecule between the atoms and hydrogen bonds that exist between molecules.

Water, H_2O, is one example of a molecule that has hydrogen bonding. When hydrogen bonds form between many water molecules, *they form a lattice of water molecules, which is very strong and flexible*. This creates a **surface tension**. Water has high surface tension from the hydrogen bonds.

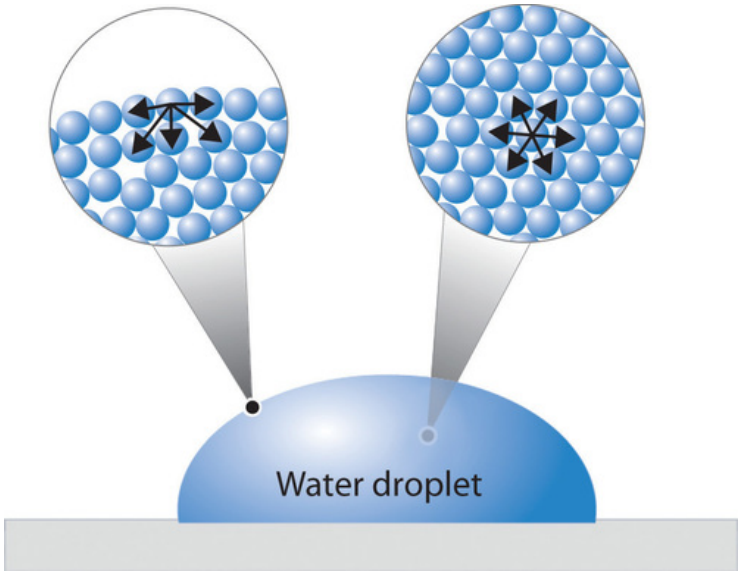


FIgure 2: An image that shows how the molecules behave in a water droplet. It shows how the hydrogen bonds between molecules cause surface tension.

Capillary Action

Module 2

- Capillary action
- Cohesion
- Adhesion

Capillary action is an application of two important properties of water: **cohesion** and **adhesion**.

Water molecules have **cohesion**, which is a strong attraction to other water molecules due to *the hydrogen bonds in water molecules*. Cohesive forces are the forces that are responsible for surface tension in water. Water molecules have strong hydrogen bonding, which leads to strong cohesive forces, resulting in water having high surface tension. Surface tension will be discussed more in module 3.

Adhesion is the *attractive force of water to surfaces that are not water.* The strength of the adhesive forces depend on the surface that the water is coming into contact with. Water has stronger adhesive forces with surfaces that have strong positive or negative charges.

Adhesion allows water to climb up through thin glass tubes placed in a beaker of water. This process is known as **capillary action**. Glass contains hydroxide on the surface, so the water molecules are more attracted to the glass than to itself, allowing the water to travel up the glass.

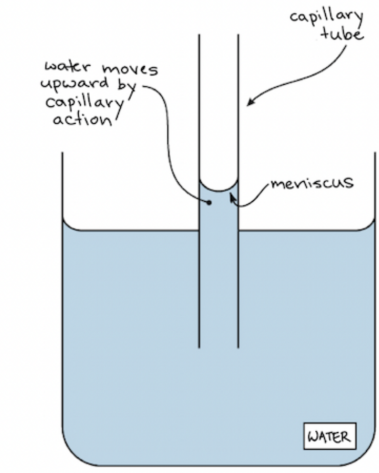
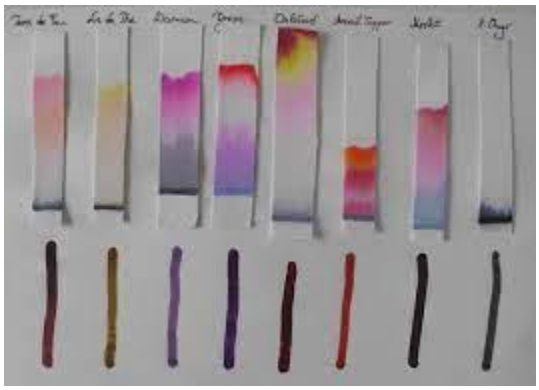


Figure 1: water moving upwards by capillary action

Background for Mentors

Module 3 ● Polarity ● Chromatography	**Polarity** is the property that certain chemical or biological compounds can have regarding the separation of charges. A simple example of this can be seen in the water molecule that we just introduced. The more electronegative oxygen bonded to the less electronegative hydrogen results in polarity. In layman's terms, we can say that the oxygen is "greedy" for electrons and thus pulls more electron density towards itself. Therefore, the oxygen atom in water has a partial negative charge, while the hydrogen atoms have a partial positive. This creates polarity. Polar compounds are attracted to polar compounds, and nonpolar compounds are attracted to nonpolar compounds. **Chromatography** is the separation of compounds in a mixture by their polarity. As the mobile phase (the solvent at the bottom of the cup which separates the compounds) travels up, it carries with it the compounds that interact with it most. So, if we were to use a polar solvent like water, the most polar compounds in the chemical mixture will travel the furthest, since they are interacting with and thus carried by the water. The least polar compounds will move the least.  **Figure 1:** A visualization of the wonders of chromatography being used to separate chemical mixtures by polarity.

Introduction

Chromatography is a widely used technique in science, both throughout science education and scientific research. It is a continuously evolving process which allows for analysis in a number of related fields. Most importantly chromatography can be examined on a very basic level, and can be easily practiced and observed by mentees!

Concepts to Introduce

- Introduce the concept of polarity in molecules
    - It might be necessary to introduce the concept of charges (some things have positive charge and some have negative) in order to lead into a discussion about polarity
    - Can talk about in relation to magnets
- WIth some background on charges, think about whether two positives things attract or repel, (think about magnets again)
    - We can imagine that molecules in many ways are just like magnets.

Questions to Pique Interest

- Ask mentees if they can give some examples of two substances that don't mix (oil and water etc.)
    - Follow up to see if anyone knows why that is the case or if anyone has any guesses.
    - When we put oil in water what happens?
- Ask mentees if there are things they know that mix? Why do they think these things mix but others don't?
    - Mentees might talk about how different phases don't mix (solids and gasses don't mix), yet in fact some gasses are soluble in solids.

Scientists, Current and Past Events

- https://www.chromatographytoday.com/news
    - Gives a plethora of different sources relating to how chromatography is used in science today, as well as different analytical chromatography methods and techniques.

Careers and Applications

- Chromatography is widely used in the scientific world as a method of analysis
    - In inorganic chemistry it is used as a means of analyzing products of a reaction or components of a certain solution.
- We can use chromatography in aspects of our own daily lives to separate different solutions.

Module 1: Hydrogen Bonding

Mentees will be dropping drops of water on a penny to see how the surface tension makes the water form a “bubble-like” shape. Mentees will observe how many drops they can do before the surface tension breaks.

Teaching Goals	**Materials**
1. **Hydrogen Bonding:** A type of intermolecular force that forms between a hydrogen atom and a strongly electronegative atom. 2. **Surface Tension:** Tension of the surface film of a liquid caused by the attraction between particles in the surface layer	• Water • 1 Penny per mentee • 1 Pipet per mentee • 1 Cup per group

Procedure

1. Hand out one cup of water per group and one penny and one pipet per mentee
2. Have the mentees guess how many drops of water they can drop on the penny before the surface tension breaks and it spills over.
3. Drop one drop of water each time and have mentees count the number of drops.
4. See how many drops mentees were able to drop and have them compare in their groups.

Figure 1: Water drops on penny forming a bubble-like shape from surface tension

Classroom Notes

It might get messy as mentees use pipet and try to drop it on the penny.

Module 2: Capillary Action

Mentees will observe a demonstration of capillary action using water and food coloring.

Teaching Goals	**Materials**
List and explain/define the 1-3 main concepts you want to focus on *for this specific module*. For example... 3. **Adhesion:** the attractive force of water to surfaces that are not water. 4. **Cohesion:** a strong attraction to other water molecules due to the hydrogen bonds in water molecules 5. **Capillary Action:** the action of water traveling up a small tube against gravity, due to strong adhesive forces.	• 3 beakers • Water • Red food coloring • Blue food coloring • 2 paper towels

Procedure (Demonstration):

1. Line up three beakers in front of the mentees. Make sure they are close together.
2. Fill the outer two beakers with an equal amount of water.
3. Put a few drops of red food coloring into one of the beakers of water, and a few drops of blue food coloring into the other beaker of water.
4. Wet two paper towels and roll them up so that they can fit through the mouth of the beakers.
5. Put one end of the paper towels in each of the red and blue colored water beakers, and have the other two ends of the paper towels meet in the middle beaker. See Figure 1 for reference.
6. Have the mentees predict how the colors will travel.
7. Since this process is relatively slow, leave the beakers off to the side and continue to module 3.
8. At the end of the lesson, show the beakers to the mentees again and explain why the water traveled.

Figure 1: Paper towels and beaker setup.

Classroom Notes:

Make sure to have a way to transport the entire system as one, if it needs to be moved out of the way for Module 3.

Module 3: Chromatography

Mentors will observe how different compounds in marker ink separate due to differing properties and interactions with the water.

Teaching Goals	**Materials**
List and explain/define the 1-3 main concepts you want to focus on *for this specific module.* For example... 1. **Polarity**: a separation of electric charge leading to a molecule or its chemical groups having an electric dipole moment 2. **Chromatography**: the means of using a fluid to separate the various components of a solution that we are interested in	• One paper cup per student • Water • One coffee filter per student • Pack of washable markers (5-6)

Procedure

1. Fold the coffee filter into half, then repeat twice more for a small triangle.
2. With washable markers, ask students to color the tip of the folded coffee filter. **Tip**: Using the color black will likely lead to the most interesting results visually.
3. Once done coloring, place the coffee filter in a cup filled with a very little amount of water. While the very bottom colored portion will be submerged, make sure that some of the colored portion stays **above** water.
4. Over the course of 10-15 minutes, the colors will flow up the coffee filters to separate into compounds and make a beautiful design for students to take home!
5. Explain how this experiment demonstrated all that we talked about: hydrogen bonding, capillary action, and chromatography!

Figure 1: Folded coffee filter, paper cup, and marker.

Classroom Notes

Since this may take a few minutes, after placing the coffee filters in the cups, have students turn to the demo from Module 2 for discussion.

Conclusion

Mentors should wrap up by summarizing the different ways in which specific features of water give rise to the concept of chromatography finally summarized in the final module of the lesson. Mentors should specifically try to ask mentees questions that might lead them to make these connections on their own.

References

- Cohesion and Adhesion in Liquids, Pressbooks, http://pressbooks-dev.oer.hawaii.edu/collegephysics/chapter/11-8-cohesion-and-adhesion-in-liquids-surface-tension-and-capillary-action/#:~:text=called%20cohesive%20forces.-,Attractive%20forces%20between%20molecules%20of%20different%20types%20are%20called%20adhesive,effect%20is%20called%20surface%20tension.

- High Performance Liquid Chromatography, Wikipedia, https://en.wikipedia.org/wiki/High-performance_liquid_chromatography

Summary Materials Table

Material	**Amount per Site**	**Expected $$**	**Vendor (or online link)**
Paper cups	1 per student	Bechtel	Amazon
Coffee Filters	1 per student	$2	Amazon
Washable Markers	1 pack per table	$15	Amazon
3 glass jars	3 per site	0	
Water	Sink in classroom	0	
Red food coloring	1 per site	$5	Amazon
Blue food coloring	1 per site	$5	Amazon

Paper towels	5 per site	$0	
Pennies	1 per mentee	26 cents	
Pipette	1 per mentee	In bechtel	