Lab: Exploring Intermolecular Forces and Properties of Liquids

FOR THE TEACHER

Summary
In this lab, students will compare and assess the effects of polarity and intermolecular forces of different liquid samples.

Grade Level
High School

NGSS Alignment
This lab will help prepare your students to meet the performance expectations in the following standards:

- **HS-PS1-3**: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **Scientific and Engineering Practices**:
  - Analyzing and Interpreting Data

Objectives
By the end of this lab, students should be able to

- Identify intermolecular forces that will act on a given substance.
- Explain why certain streams of liquids are deflected by a charged object.
- Recognize that increased strength of intermolecular forces results in increased surface tension.

Chemistry Topics
This lab supports students’ understanding of

- Polarity
- Intermolecular Forces
- Surface Tension
- Lewis Dot Structures
- Bonding

Time
**Teacher Preparation**: ~1 hour
**Lesson**: 1 hour

Materials
Activity 1 (make 3 sets of the following):

- 3 burets (labeled with contents)
- 3, 250 mL beakers (labeled to match the contents of each buret)
- 3 ring stands
- 3 buret clamps
- Approximately 60 mL of a Non-polar liquid in a buret (examples: cyclohexane, toluene, hexane)
- Approximately 60 mL Water in second buret
- Approximately 60 mL Alcohol in third buret (examples: Ethyl or Isopropyl)
- Balloons
- Combs (optional)
- Label tape and marker

Activity 2 (make 3 sets of the following):

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Lower Merion
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Thanks to:
Dow Chemistry Teacher
Summit
- 2 pennies
- 2 beakers (100 mL, 150 mL, or 250 mL)
- 2 pipettes
- Approximately 30 mL Alcohol for penny (choose different alcohol than what was used in activity 1 buret), (examples: propanol, ethanol, isopropyl)
- Approximately 30 mL Water
- Label tape and marker

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.
- Use caution, as Cyclohexane and alcohols are flammable.

**Teacher Notes**
- Teacher should gather 3 sets of materials for each of the two lab activities, labeling burets and beakers. This may take ~1 hour.
- This lab can be done prior to explaining intermolecular forces and polarity or as a further investigation into intermolecular attractions.
- I find that it is best if you set up 3 stations for Activity 1. Each station will have 3 burets filled up to the top with one of the liquids, 3 beakers and 3 balloons (or combs). I find it best to label the buret with the liquid in it and place a beaker under the buret to catch the liquid also labeled. This way students can pour the liquid back into the buret and the waste is minimal.
- I blow up a balloons in advance and leave one at each station for the students. However, you can allow students to do this to minimize teacher prep time.
- I also set-up 3 stations for Activity 2. Each surface tension station will have 2 pennies, 2 droppers and two labeled beakers. One beaker will be water and the other will be a different alcohol than in the buret used in Activity 1. The pipettes will be put into the beakers so that students can use one pipette for one solution.
- Three stations for each of the lab activities allows for small groups of students to do one activity and then move to the other one. The order of completion of the activities does not matter.
- If time is short you could also use this as a demo, but I find students enjoy it more when they can see the results themselves and then try to figure it out.
- During the activity, I do make sure students are getting the correct results for the streams of water, cyclohexane and alcohol. If they don’t I ask them to do it again. The students should see the biggest bend with water, then alcohol and nothing with cyclohexane. You will find that sometimes the students put the balloon under cyclohexane and the balloon pops. This is because of the interaction of cyclohexane and the rubber. The latex balloon will absorb the cyclohexane and swell causing it to pop. This is because the latex easily absorbs “oily solvents”.
- I make sure students are getting the correct results with the penny activity. The water should be about twice the amount of the alcohol. Sometimes students miss the drops falling off the side of the penny for the alcohols and therefore miscount.
- For the penny lab we do not do a non-polar liquid since it will have even fewer drops than the alcohol, but it is a great discussion to have after the fact to see if students understand this concept.
- This unit on Intermolecular Forces can be tied in to many everyday things the students encounter. I talk to my students about water bugs walking across the water. Everyday foods like ketchup, molasses, honey and viscosity or “thickness” of liquids.
FOR THE STUDENT
Lesson
Exploring Intermolecular Forces and Properties of Liquids

Background
In this lab, you will be conducting two lab activities to explore intermolecular forces. One activity will be used to determine if a liquid is polar or not by using a comb or balloon and how it effects a stream of liquid. The second activity will look at surface tension and how the intermolecular forces can affect it.

Activity 1: The Attraction of Liquids

Objective
To explain why certain streams of liquids are deflected by a charged object.

Materials
- Buret
- Water
- Rubbing Alcohol
- Non-polar liquid (Cyclohexane, Toluene, Hexane)
- Balloon or Comb

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.
- Keep all materials away from heat sources.

Procedure
1. First use the beaker labeled “water”. Make sure the buret is filled to the top with water. If it is not, refill it from the liquid in the beaker label water.
2. Inflate a balloon, and tie it off. Rub it through your hair or on your body to create friction. (Note: you may use a comb instead of a balloon).
3. Place a beaker under the buret.
4. Open the buret so that a constant stream of liquid flows into the beaker.
5. Bring the balloon close to the fluid stream, but don’t touch it with the balloon. Record any observations in the data table below.
6. Close the buret when you are done and refill the buret with the water from the beaker.
7. Repeat steps 1-6 of the procedure with alcohol and then again with cyclohexane

Data Table

<table>
<thead>
<tr>
<th>Substance in Buret</th>
<th>Observations of Interaction with Balloon/Comb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td></td>
</tr>
</tbody>
</table>
Questions
1. Draw Lewis structures for water (H₂O), ethyl alcohol (CH₃CH₂OH), and cyclohexane (C₆H₁₂)?
2. Which of these structures has hydrogen bonding?
3. Which of these structures has dipole-dipole interaction?
4. Why did the cyclohexane and water behave differently? Explain your answer using at least 3 complete sentences.
5. Why are the polar molecules attracted to the balloon, but the nonpolar molecules are not? Explain your answer using at least 3 complete sentences.

Activity 2: The Penny Drop

Objective
To recognize that increased strength of intermolecular forces results in increased surface tension.

Materials
- Pennies
- Pipettes
- Water
- Rubbing Alcohol

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.
- Keep all materials away from heat sources.

Procedure
1. Place a penny on the table.
2. Carefully add drops of water, one by one, to the top of the penny with the pipette. Count the drops as they are added. Your goal is to put as many drops on top of the penny without any water falling onto the table.
3. Record the number of drops of water added to the penny before the water spilled onto the table.
4. Observe the penny from the side during the process.
5. Dry the penny.
6. Each person in your group should repeat these steps. Record each person’s data.
7. Next, carefully add drops of alcohol, one by one, to the top of the penny with the
pipette. Count the drops as they are added. Your goal is to put as many drops on top of the penny without any alcohol falling onto the table.
8. Record the number of drops of water added to the penny before the water spilled onto the table.
9. Observe the penny from the side during the process.
10. Dry the penny.
11. Each person in your group should repeat these steps. Record each person’s data.

Data Table

<table>
<thead>
<tr>
<th></th>
<th>Number of Water Drops Held</th>
<th>Number of Alcohol Drops Held</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions
1. Which liquid had the higher average number of drops?
2. Draw a Lewis Structure for water and the alcohol:
3. What is the shape of a water molecule?
4. What intermolecular forces are present in water?
5. What intermolecular forces are present in alcohol?
6. Which liquid, water or alcohol, has STRONGER intermolecular forces? Explain using at least 2 complete sentences.
7. Why do you think that liquid was able to stay on top of the penny better?
8. Justify your answer in terms of intermolecular forces. Use at least 2 complete sentences.
9. Suppose you were to try this experiment with acetone (CH₃COCH₃), a liquid that does not have any hydrogen bonding. How would you expect the result to be in comparison to the water and alcohol? Explain your answer using at least 2 complete sentences.

Extension
Find a natural phenomenon that occurs dealing with surface tension. Some ideas are water beading on a car after being waxed, water striders walking across a pond, and describe it below.