# How Many Drops

## Overview

Students will determine how many drops of water, rubbing alcohol, and vegetable oil can be placed on a penny before the liquid spills over. In the process of comparing this quality of the three liquids, students learn about cohesion, adhesion, polarity, and surface tension. Students will propose an explanation and a test for their explanation. It is not necessary for them to explain that water's greater cohesion accounts for more drops of water than the other liquids on the pennies (you'll get to that later). However, students are asked to propose testable explanations and reasonable tests. They won't have to execute the tests because many tests would be too difficult, but they do have to explain how and why their test would work. You will question them to determine whether their test could confirm or refute their explanation.

## Background

Water molecules form bonds of attraction, and they form some of those bonds *between each other*. The bonds are electrical, like the static electric attraction between a balloon and the wall. The attraction is between electric charges unevenly distributed around the smallest bits of water called molecules. The hydrogen parts of the molecule have a bit of extra positive charge, and the oxygen part has a little extra negative. These parts are like positive and negative "poles." That's why water is called **polar**. Each end of a water molecule is attracted to the oppositely charged end of another water molecule. This is called **hydrogen bonding**. The hydrogen bonds make water tend to stick to itself, a quality called **cohesion**. Cohesion shapes the way water behaves. It causes water to form drops. It also produces the skin-like surface on top of water called surface tension. When insects walk on water, they walk on surface tension. The static charges can also make water stick to other things (like glass), a quality called **adhesion**.

Oil is not polar, so it attracts itself very little. Because of this, oil spreads out on a penny to form a thin layer. Rubbing alcohol molecules are slightly polar, with a weak attraction between molecules. On a flat surface, a drop of rubbing alcohol forms a flatter and smaller drop than water. The difference in 'polarness' among the three liquids makes them behave differently when you drop them carefully on the surface of a penny. You can pile water into a dome shape before it spills over. You can also pile up rubbing alcohol, but it spills over before it forms much of a dome. Oil will barely pile up at all. As a result, you can put much more water on a penny.

## Materials

*Materials to be supplied by the teacher or the students are marked with an asterisk.

**Materials for the whole class**

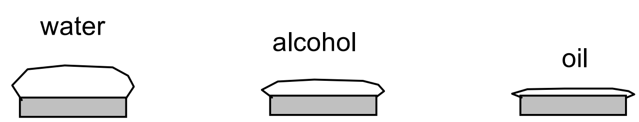
- 1 bottle rubbing alcohol
- 1 bottle vegetable oil
- *water
- *paper towels

**Materials for small groups (groups of 2)**

- 3 disposable pipettes
- 1 penny
- 1 9-oz cup containing about 1/4 inch of water
- 1 9-oz cup containing about 1/4 inch of rubbing alcohol
- 1 9-oz cup containing about 1/4 inch of oil
- 3 paper towels

## Preparation

- Pour three 9-oz cups for each group: one with about 1/4 inch of water, one with1/4 inch of rubbing alcohol, and one with 1/4 inch of vegetable oil.
- Set out the remaining materials for each group of 2
- Be ready to insist that students draw table-level views of the pennies and liquids. Students will skip this step if left to their own devices, but they gain from observing and drawing. Their drawings might look like this:

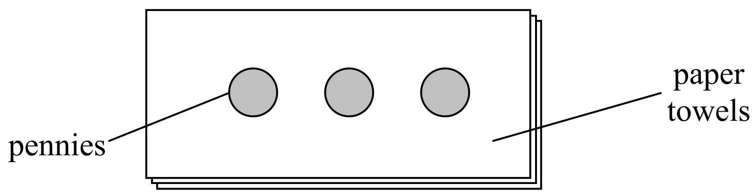


## Procedure for a team of 2 students

[There is a black line master of these instructions at the end of this section.]

1. Put a pipette in each of the 3 plastic cups with the three different liquids. During the activity, keep each pipette with its own liquid and do not use it with any other liquid.

2. Keep your paper towels folded and pile them in a neat stack, smoothed flat. Set the 3 pennies a few inches apart in the middle of the paper towel. In your notebook, record how you arrange the heads and tails of the 3 pennies. Same sides up? Which sides? Different sides up? Why?




   [An alternative could be to require all students to set up their pennies exactly the same way—all heads up or all tails up—and to label each penny with the liquid it will get. This would reinforce the notion of uniformity and labeling in experimental design. On the other hand, a discussion of the variability of results might bring out the same points.]

3. In your notebook, predict a) which of the three liquids will allow you to put the most drops on a penny, and b) which of the three liquids will allow you to put the fewest drops on a penny. Give your reasons for each prediction.

4. Drop one of the liquids on a penny slowly and gently. Note how far you are dropping from. Is it near the penny or higher up? How high? Count the drops. Stop when a drop makes the liquid overflow the edge of the penny and don't count the drop that caused the overflow. Record the number of drops and the liquid used. Wipe off the penny and repeat 2 more times. Record the number of drops for all 3 trials and circle the middle number. On the last trial, before the liquid overflows, place your eye at table level. View the penny and liquid from the side. Draw what you see in your notebook. Label the drawing with the name of the liquid used.

5. Repeat step 4 with a second liquid. Again record the number of drops for 3 trials. Circle the middle number from the 3 trials. On the last trial, view the penny and liquid from the side at table level, draw what you see in your notebook. Label the drawing and the number of drops with the name of the liquid used.

6. Repeat step 4 with the third liquid. When finished, your notebook should contain a record of all 3 trials of each liquid with the median indicated. It should also contain labeled drawings of the three pennies with liquids as seen from table level.

7. When you are done, use clean spots on the paper towels to wipe up any liquid that has soaked through to the tabletop.

## Reflection/Discussion

**Teams of 4 Students Discuss and Report in Notebooks**

1. Which liquid had the highest median number of drops on the penny? Lowest? In between?
2. As a team, discuss why you think the medians are different. Try to explain so that everyone in the group agrees. Write the explanation you agree upon. If you don't agree, record all of the explanations.
3. Design a way to test your explanation. You won't have to do the test, so it can include materials not on hand. However, the test should show if your explanation makes sense.
4. Designate someone in your team to report the explanation and test to the class.

## Reflection/Discussion (for the teacher)

Ask the class which aspects of the procedure are controlled and which are not (there are many of each). Aspects such as coin type, side of coin used, temperature, humidity, time of day, liquids used, types of pipettes, etc., are usually controlled. Condition of pennies, dropping techniques, and cleanliness of pipettes, etc., are usually uncontrolled.

Put a chart on the board like the one below and ask recorders from each group to fill it in. Ask reporters questions about their explanations and proposed tests as necessary. Check that 1) their explanations are consistent with their data, and 2) their tests fit the explanations.

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| | Median # of drops | | | | |
|---|---|---|---|---|---|
| Team Name | Water | Alcohol | Oil | Hypothesis | Test of Hypothesis |
| | | | | | |
| | | | | | |
| | | | | | |

**Debriefing**

Students are unlikely to know about hydrogen bonds, cohesion, or surface tension. They might say the "heaviest" liquid comes off the penny with the fewest drops. They might want to weigh the liquids. If so, ask them to weigh the same volume of each liquid. This could lead to a good discussion of density. If they say that oil is densest, so the penny holds less of it, they might test this by layering the three liquids. If oil were densest, it would be on the bottom. On the contrary, it will be on top. This doesn't support the explanation, but the test does shed light on the explanation, so it is a success.

Students may also say that oil is more viscous, so it oozes off the penny. They can test viscosity by timing the descent of a BB through equal columns of the liquids, or racing drops down an inclined plane.

Other teams might explain that drops of different liquids are different sizes, and test this by counting drops needed to fill a small graduated cylinder to the 5 ml mark.

If students correctly explain that cohesion allows more water drops on the penny, a reasonable test would use detergent to disrupt hydrogen bonds. Few students know that detergents do this, but if someone proposes it, they could add a few drops of detergent to water before dropping it on the penny, decreasing the number of drops the penny will hold. With a good supporting argument, the test could support the hypothesis.

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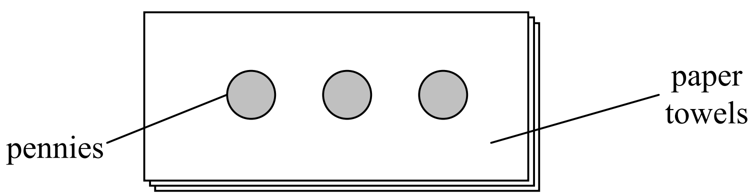


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