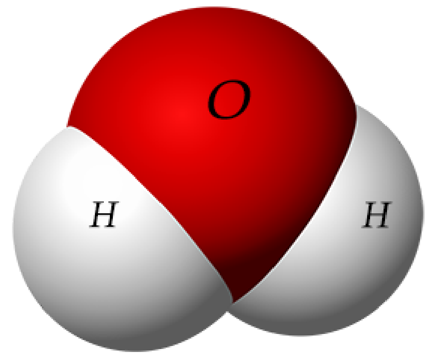
Name: ____Date:________

Lab Investigation: Properties of Water



Water is a ***polar*** molecule. The oxygen atom in water has a greater ***electronegativity***, or a stronger "pull," on the electrons that it shares with the two hydrogens it is covalently bonded to. As a result, the molecule ends up having a **partially negatively charged end**, near the **oxygen**, and a **partially positively charged end** near the **hydrogens**. Much like a magnet, opposite charges will attract and similar ones will repel so that the slightly negatively charged oxygen of one water molecule will be attracted to the slightly positively charged hydrogen of a neighboring water molecule. This weak attraction and "sticking together" of polar molecules is called ***hydrogen bonding***.

All life depends upon the unique features of water which result from its polar nature and 'stickiness.' Some of the unique properties of water that allow life to exist are:

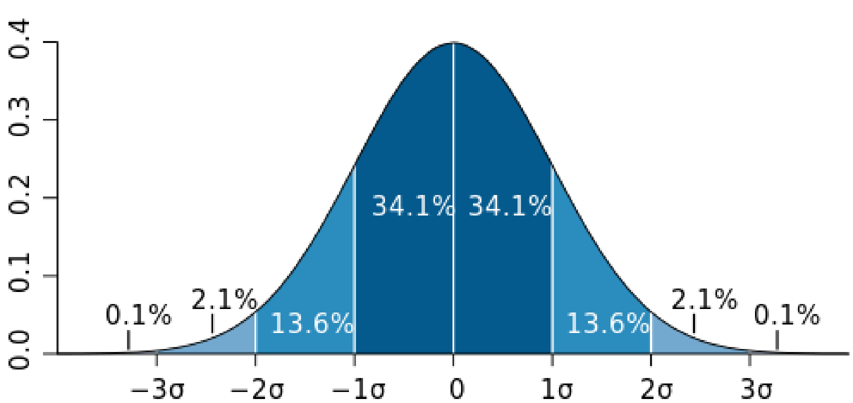
- It is less **dense** as a solid than as a liquid (ice floats)
- It sticks to itself –***cohesion***– cohesion is also related to surface tension.
- It sticks to other polar or charged molecules –***adhesion***– adhesion results in phenomena such as capillary action.
- It is a great ***solvent*** for other polar or charged molecules.
- It has a very ***high specific heat*** – it can absorb a great deal of heat energy without increasing in temperature
- It has a neutral **pH** of 7, which means the concentrations of H^+ and OH^- ions are equal.

Introduction to Statistics:

Statistical analysis is used to collect a sample size of data which can infer what is occurring in the general population**. *Standard deviation (SD)* (often reported as +/-) shows how much variation there is from the average (mean).**

If data points are *close* together, the standard deviation will be *small*. If data points are *spread out*, the standard deviation will be *larger*. Typical data will show a ***normal distribution*** (bell-shaped curve). In normal distribution, about 68% of values are within one standard deviation of the mean, 95% of values are within two standard deviations of the mean, and 99% of the values are within three standard deviations of the mean $\bar{x}$.

The formula for standard deviation is shown below, where $\bar{x}$ is the mean, x_i is any given data value, and *n* is the sample size. Consider the following sample problem.



$$SD = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

Quickcheck: On a normal distribution curve, what percentage of data points will be within 1 standard deviation of the mean? ____68.2%_______ How many will be within 2 standard deviations of the mean? __95%________

Practice Problem: The length in millimeters of 6 worms were: 96, 88, 86, 84, 80, 70.

Step 1: Find the **Mean ($\bar{x}$)**. ____84_________

Step 2: Determine the **Deviation $(x_i - \bar{x})^2$** from the mean for each value and square it, then add up all of the total values.
___376________

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

Step 3: Calculate the **Degrees of Freedom (n-1)**. ___5___________

Step 4: Put it all together to find **s**. __9_________

Step 5: Determine the data range for **one standard deviation**: _____75 to 93__________
two standard deviations: ___66 to 102___________

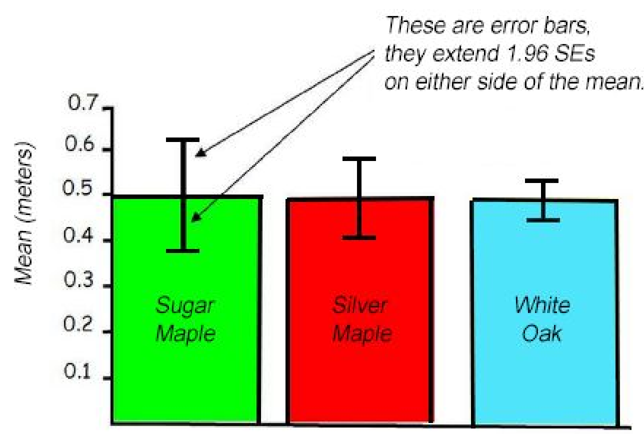
Standard error of the mean **(SE)** is used to represent uncertainty in an estimation of mean and accounts for both sample size and variability. The formula used to calculate "standard error of the mean" is shown below. **As standard error grows smaller, the likelihood that the sample mean is an accurate estimation of the population increases.**

Using the data from the standard deviation example above, the mean is 84 and the standard deviation is 9. What is the SE?

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

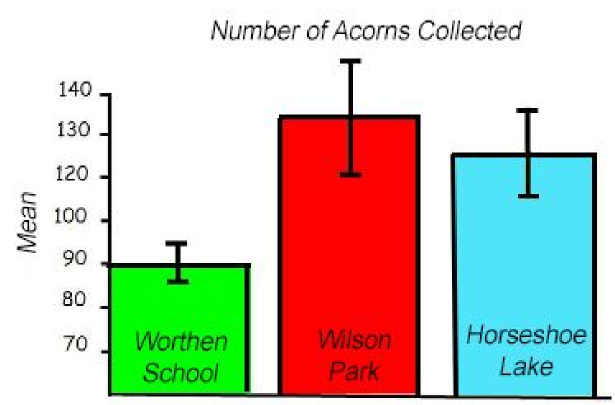
____3.67________

It is common practice to add standard error bars to graphs, marking one or two standard error(s) above and below the sample mean (see figure to the right). Such bars give an impression of the ***precision*** of estimation of the mean in each sample. Typically, the length of the bars above and below the mean and the overlap of the bars as compared to one another is analyzed (see figures to the right). The ***length*** of the bars shows the spread around the mean. **Shorter bars indicate less variability from the mean**. If two or more error bars are the *same* size, they have *similar* spreads around their means. **If a bar is longer than others, it has a larger spread around its mean.** In the graph shown, the white oak data shows the least amount of variation around its mean.



When the ***ranges*** of bars ***overlap***, this indicates that there is ***NOT*** a significant difference in averages and data sets. If the ranges of bars do not overlap, there *may* be a significant difference in averages and data sets.

Notice that in the last image, **the error bars tell us that we can be 95% confident (2 SEM) that the number of acorns collected at Worthen School is significantly different from the Wilson Park and Horseshoe Lake sites.** Things are not as clear-cut between Wilson Park and Horseshoe Lake because the error bars overlap.

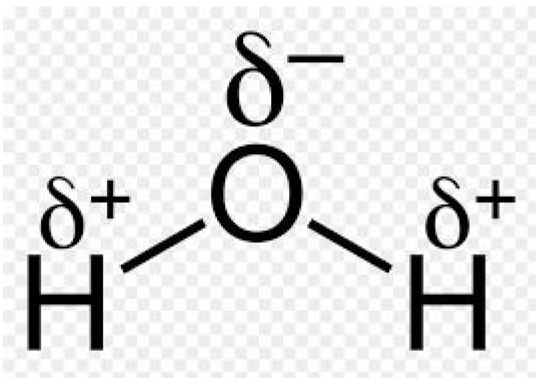


Pre-Lab Questions: Use the above background information and your textbook to answer the following questions.

1. Why is water considered to be polar?

Because there is à partial negative and à partial positive; the oxygen atom hogs all of the electrons.

2. Sketch a molecule of water (include the partial charges).



3. Which type of bonds form between the oxygen and hydrogen atoms of TWO DIFFERENT water molecules?

Hydrogen bonds

4. Which type of bonds form between the oxygen and hydrogen atoms of WITHIN a water molecule?

Polar covalent bonds

5. Explain what shorter error bars mean when you are analyzing data from a graph.

Shorter error bars in à graph mean that we can be confident that the mean of the data set is more accurate than à graph with à larger error bar.

Question to Investigate: How will soap or alcohol affect the hydrogen bonds between different water molecules?

Write a Hypothesis: __I think soap or alcohol will disrupt the hydrogen bonds water molecules have. The properties that just water has will change when soap or alcohol are added.________________________________

Materials: Penny, water, soap, pipette, paper towel, 70% rubbing alcohol

Procedure:

1. Obtain a DRY penny (or any coin) and place it on a DRY paper towel.
2. Using a clean pipette, add water to the penny drop by drop until it overflows. **Be sure to count the drops!** Record the number of drops for Trial 1 in Data Table 1 below.
3. Repeat steps 1-2 for a total of five trials.
4. Place 1 ml of soap in 50 ml of water to create a solution. Test the number of drops of the soapy water that can fit onto the penny. Repeat for a total of five trials.
5. Repeat the experiment using 70% rubbing alcohol. You do not need to dilute it with water, it is already diluted. Repeat for a total of five trials.

Data Collection:

Data Table 1: Number of Drops of Distilled Water Contained on the Surface of a Penny

Trial	# Drops Water	# Drops Water + Soap	# Drops 70% Alcohol
1	37	15	18
2	38	12	25
3	28	15	21
4	35	20	25
5	34	9	26
Average	34.4	14.2	23

Data Table 2: Statistical Analysis of the Number of Drops of Distilled Water Contained on the Surface of a Penny

Calculation	# Drops Water	# Drops Water + Soap	# Drops 70% Alcohol
Mean	34.4	14.2	23
Standard Deviation	3.91	4.1	3.4
+/- 1 std dev	30.49 to 38.31	10.1 to 18.3	19.6 to 26.4
+/- 2 std dev	26.58 to 42.22	6 to 22.4	16.2 to 29.8
Standard Error	1.75	1.8	1.52
+/- 2 SEM	32.65 to 36.15	10.6 to 17.8	19.96 to 26.04

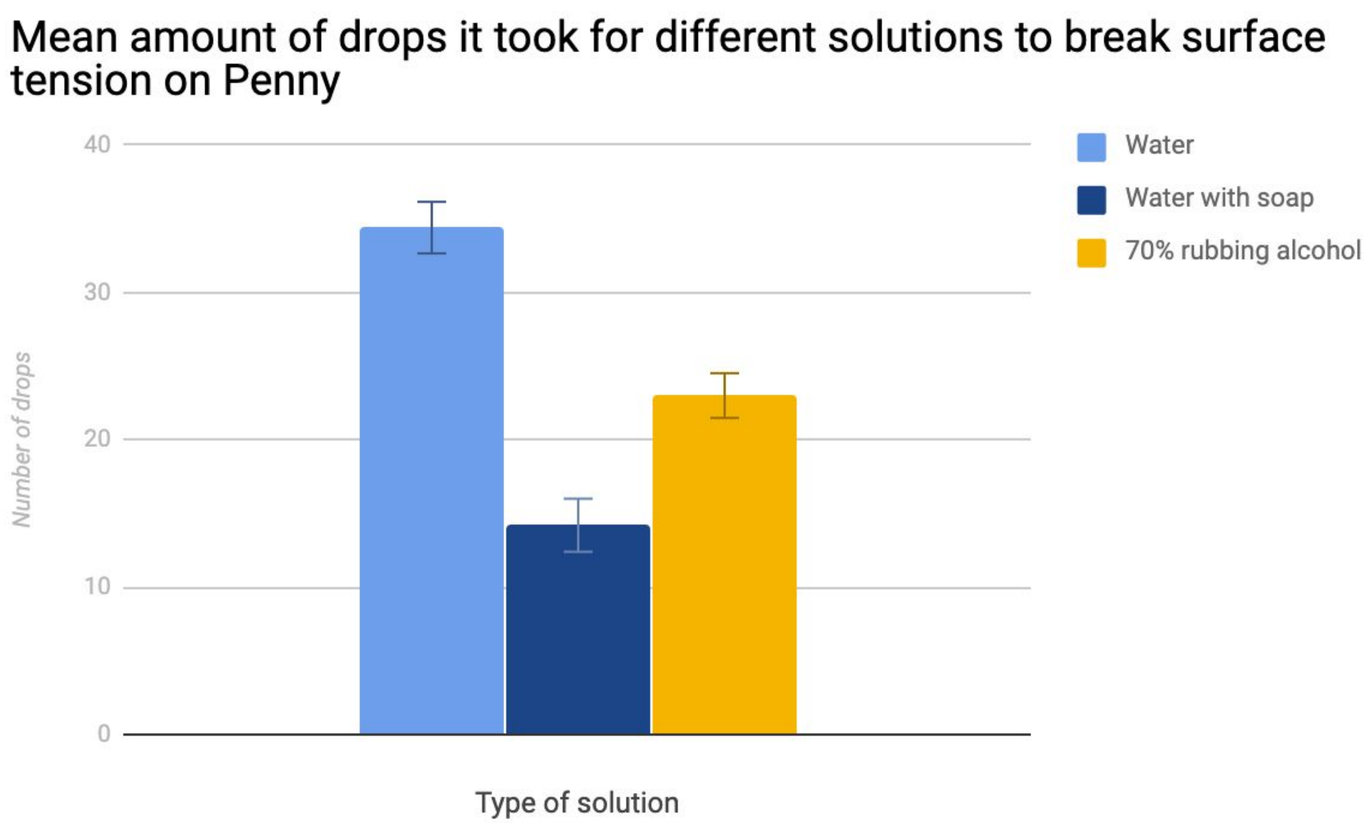
$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}} \qquad SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

For additional support, check out these tutorials:

- Standard Deviation (Bozeman Science) 8 mins
- Standard Error (Bozeman Science 8 mins)

Graph Data

Create an appropriately labeled bar graph to illustrate the sample means for the penny within 95% confidence (+/- 2 SEM). **Don't forget a title that includes the independent and dependent variables and axes labels with units.**



1. Make a **Claim** about how soap and alcohol affects hydrogen bonds between water molecules. This can be written as two separate claims, be sure that your claim relates to your hypothesis.

When water is mixed with soap, the hydrogen bonds weaken which results in the surface tension weakening. When water is by itself, the hydrogen bonds stay the same and the surface tension is at its strongest. When 70% rubbing alcohol is used, the hydrogen bonds weaken, but not as much as when water is mixed with soap.

2. Using data from this experiment, provide **Evidence** from your investigation that supports the claim(s).

In the table and graph above, the true mean for the average amount of drops in water is between 32.65 - 36.15. The true mean for water with soap is between 10.6 - 17.8, and the true mean for 70% rubbing alcohol is between 19.96 - 26.04. Because none of these error bars overlap, we can say (with 95% confidence) that water has the highest average amount drops, rubbing alcohol is second, and water with soap is last.

3. Using background knowledge and data from this lab, provide **Reasoning** that uses the evidence to justify the claim and comment on how confident you are in your conclusions. Here, you may want to include deductive reasoning that uses the properties of water to explain why you obtained the results.

Two properties that water has in general are cohesion and adhesion. Cohesion is the property where water molecules stick to each other. Cohesion is used in this experiment as surface tension, where the number of drops was counted until the point the surface tension broke on the surface of the penny. Adhesion is the property where water sticks to other polar molecules. In this experiment, the property of cohesion was focused on. The three solutions all had some amounts of water in them. The amount of drops it took to break surface tension, however, was different for all of them. It is because of this that one can conclude the other two solutions, besides water, have à weakened bond between water molecules. Substances such as the soap or the alcohol might be blocking some of those hydrogen bonds which would lead to them being weaker which would reduce the strength of the surface tension.

Answers to practice problems:

96, 88, 86, 84, 80, 70.

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Mean 504/6 = 84

Standard deviation

$(96 - 84)^2 = 144$
$(88 - 84)^2 = 16$
$(86 - 84)^2 = 4$
$(80 - 84)^2 = 16$
$(70 - 84)^2 = 196$

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Add together 376

Degrees of freedom 6-1 = 5

S = √ 376 / 5 = 75.2

Square root of 75.2 = 8.67 ← this is your standard deviation (S)

Step 1: Find the **Mean ($\bar{x}$)**. __84_______

Step 2: Determine the **Deviation (x_i - $\bar{x}$)^2** from the mean for each value and square it, then add up all of the total values.

___376_____

Step 3: Calculate the **Degrees of Freedom (n-1)**. ______5_______

Step 4: Put it all together to find **s**. _____8.67_ suggest rounding to 9______

Step 5: Determine the data range for **one standard deviations**: ___75 to 93_______
two standard deviations: ____66 to 102______

If the standard deviation is 9 (rounded up) and the mean is 84 then…

One standard deviation is 84 - 9 and 84 + 9 basically 9 above and below the mean , this means 68% of the data falls between these numbers (75 and 93)

Two standard deviations would be (84-18) through (86+18), or a range of 66 to 102

Using the data from the standard deviation example above, the mean is 84 and the standard deviation is 9. What is the SE?

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Square root of 6 (N) = 2.44
9 / 2.44 = 3.68