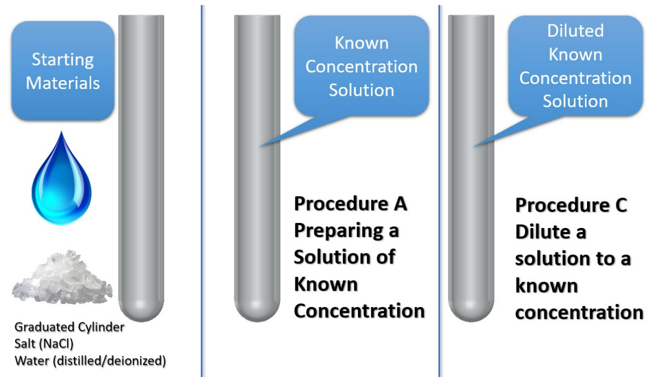
Experiment 3 – Density of Saline Solutions

This is a two-week lab. It is suggested that you complete the data collection during week one and complete calculations and graphing during week two. Your instructor may require you to turn in your data after week one for a grade.

Prior to starting this experiment, please review the video at:
https://youtu.be/vE_DWe6vcUw



Materials Needed to Complete This Experiment

- Plastic 3 mL plastic pipette
- 50 mL graduated cylinder
- 50 mL beaker
- 100 mL beaker
- 500 mL beaker
- Waste beaker
- Distilled / deionized water
- Scale that holds up to 200.0 g with 0.01 g accuracy
- Thermometer / temperature probe
- Table salt, NaCl

Common Lab Procedures/Skills in This Lab

(new skills in bold, * denotes these previous skills have videos associated with them**)**

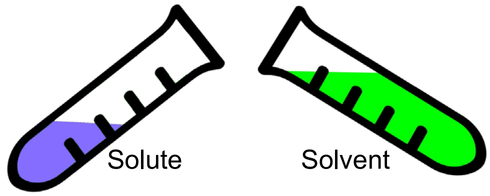
- Preparing a Solution of Known Concentration (https://youtu.be/NbfteJh0W-I)
- Equilibrate to Room Temperature*
- Record the Mass*
- Mix Well Without Spilling (No Inversion) (https://youtu.be/csTgjuXD3tg)
- Mix Well Without Spilling (With Inversion) (https://youtu.be/kMoGa_DG8K4)
- Measure the Density and Percent Composition of a Solution (https://youtu.be/BPrBQ9PdMGs)
- Deliver 2.00 ml Using the Pipette*
- Repeat the Measurement Multiple Times to Allow You to Determine Precision
- Dilute a Solution to a Known Concentration (https://youtu.be/6O7kjZFyhsU)
- Calculate the Molarity (https://youtu.be/If48zzc16Sw)
- Calculate the Density of The Saline Solutions (https://youtu.be/n1sh2IGr-7Q)
- Calculate the Percent Composition of NaCl (https://youtu.be/5eS388xCdbg)
- Calculate the Concentration of a Diluted Solution (https://youtu.be/nWdGjettNF0)
- Graphing by Hand (https://youtu.be/Bo1aWUjlemw)
- Making a Best Fit Line by Hand (https://youtu.be/fDkIGroiL4E)
- Graphing Using Excel (https://youtu.be/5WdTyJJ4n9c)

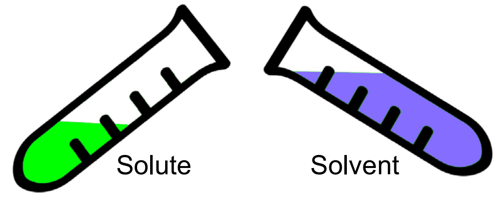
Introduction

The goals of this lab are

- To learn how to prepare a solution with a known concentration
- To learn how to prepare a diluted solution with a known concentration
- To graph (by hand and using a spreadsheet program) the relationship between the density of a solution and either the molarity of a solution or the percent composition of a solution.

A solution is a homogenous mixture of two or more compounds. The solvent is the component of the solution present in the greatest quantity. A solute is a component of a solution that is present in a smaller amount than the solvent. There can be many solutes in the same solution (e.g., sea water). There can only be one solvent. Most of the solutions in General Chemistry (and all of the solutions in this experiment) have water as the solvent.





As shown above, the liquid in the larger quantity is called the solvent and the less quantity is called the solute. Students typically assume that water is always the solvent, please do not fall into this belief.

Conditioning each piece of labware will be important in this lab. Recall conditioning is the process by which you rinse a container with the solution you are going to put into it. Conditioning will keep the concentration of your solutions from changing when you transfer them from one container to another.

One of the worst possible things for a scale (or any mechanical/metal piece of equipment is salt. Salt is one of the principle materials that cause the corrosion of a metal. To protect your scale, always take the beaker / weighing boat / filter paper off of the scale before placing anything onto it. Not doing this may result in material being splashed onto your scale.

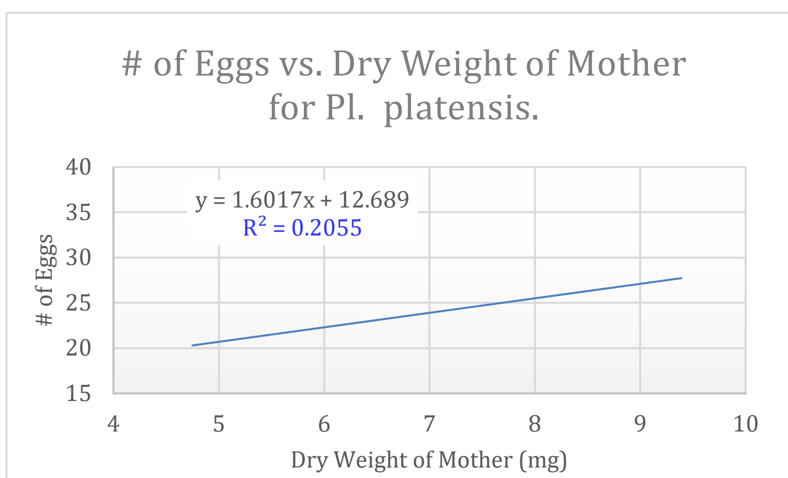
"Swirlies" in the solution are actually density variations due to incomplete mixing of the salt and water. These density variations result in variations in the index of refraction of the solution. You will know that you've mixed the solution completely when there are no more density variations (swirlies).

Percent composition, % NaCl (m/m) and % NaCl (w/w) are three ways of referring to the same thing. The "m/m" refers to calculating percent composition by dividing a mass by another mass. The "w/w" refers to calculating percent composition by dividing a weight by another weight. In chemistry, all scales read in mass. A mass measures an amount of matter.

When graphing by hand, it is important for you to be able to make a good "best fit line" on your graph. To do this, you need a straight edge that is at least as long as the line you want to draw. The straight edge should be positioned so that it lies as closely as possible to each of the data points. Some of the data points will be above the line and some below. The distance between the data points and the line should be minimized.

As part of this lab, you will also be introduced to graphing data, adding a trendline, displaying the equation, and displaying the R^2 value. Please see the introductory materials for information on these topics.

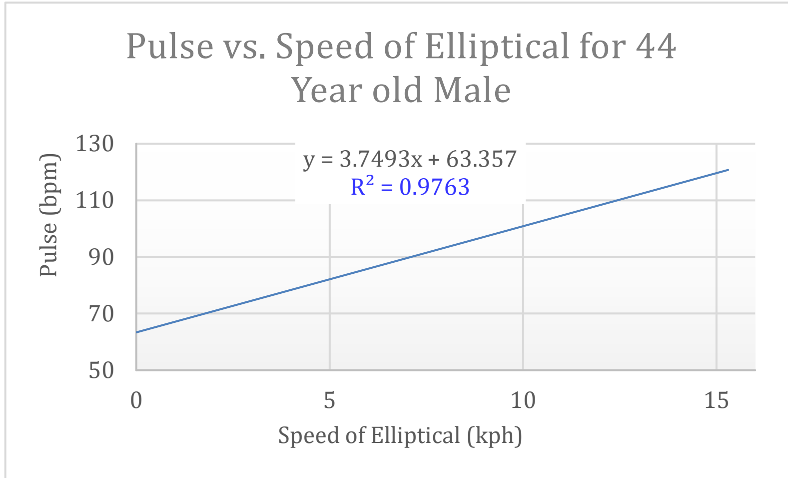
R^2 is called the "coefficient of determination" or the "square of the correlation coefficient". R^2 is related to the closeness of each point to the trendline. Technically, R^2 is the fraction or percent of the variation in one variable, such as molarity, that can be explained by the variation in another variable, such as density. Below are two examples of graphs with their R^2 values.



In the first graph, R^2 = 0.97626. Notice how *close each point is to the trendline*. For this graph, the R^2 value means that as you vary the speed of the elliptical machine, 97.6% of the variation in a person's pulse can be explained by (or is related to) the increase in the speed of the elliptical machine. Only 2.4% of the variability is not accounted for.

Since 97.6% >> 2.4%, there is very good correlation between these two variables.

In the second graph, $R^2 = 0.20552$. Notice how much *farther each point is from the trendline*. For this graph, the R^2 value means that as mass of the mother varies, only 20.6% of the variation in the expected number of eggs can be explained (or is related to) the increase in mass of the mother. 79.4% of the variability is not accounted for. Since 20.6% << 79.4%, there is a poor correlation between these two variables.



Procedure – You will work on this lab independently (no lab partners).

A. Preparing a Solution of Known Concentration
(Video 1 Procedure/Skill 1 above, https://www.youtube.com/watch?v=NbfteJh0W-I&feature=youtu.be)

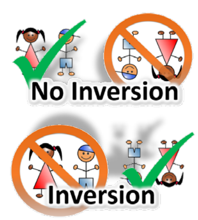
Note: This experiment is classified as a quantitative type experiment. In this section you will be making a known concentration of solution. The amount of solvent used is critical. Too much solvent and your calculated concentration will be too low, too little solvent and your calculated concentration will be too high.

1. **EQUILIBRATE** 400 mL of distilled water to room temperature in your 500 mL beaker. Record ✎ the temperature of the water after it has equilibrated.

2. Record ✎ the mass of a clean, dry 50.0 mL graduated cylinder. If your 50.0 mL graduated cylinder is not dry be sure to condition it with distilled water.

3. Ensure that your graduated cylinder is off of your scale. Add approximately 5 grams (±0.2 grams) of NaCl (table salt) and then record ✎ the mass of the graduated cylinder along with the NaCl. Be sure to provide as many significant figures as possible.

4. Add approximately 25 mL of distilled water to the graduated cylinder. Mix well without spilling (no inversion)



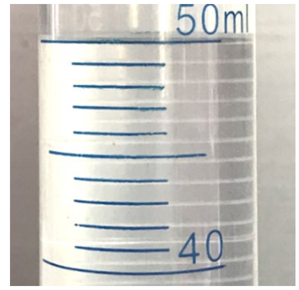
   a. Swirl the graduated cylinder until the salt dissolves without spilling the solution. This may take a couple of minutes.

   b. You will know that you're done when all of the salt crystals have dissolved and there are no "swirlies" in the solution.

   c. Do not cover and invert the solution to mix as this will decrease the total volume of solution. (Video 2 Procedure/Skill 4 above - https://youtu.be/csTgjuXD3tg)

5. Add distilled water to the graduated cylinder until it is filled exactly to 50.0 mL. Use a pipette, conditioned with distilled water, to add the last few mLs or drops to ensure that the graduated cylinder is exactly at 50.0 mL. Do not add over 50.0 mL because you cannot take any solution out of the graduated cylinder.

6. Take a picture 📷 of the water at the 50 mL mark of your graduated cylinder. Try to get a closeup like the image to the right.



7. Mix well without spilling (with inversion). This is typically done with a volumetric flask which has a stopper. For our class we will be using the graduated cylinder and try to mimic the process. Cover the top of the graduated cylinder with either (i) a piece of plastic wrap and your hand or (ii) a gloved hand. With the top covered, invert the graduated cylinder to mix. If you do this, be careful that none of the solution leaks out or spills until the solution is well mixed. The volume is critical prior to the mixing. After it is mixed, if a little bit spills out that is acceptable. (Video 3 Procedure/Skill 5 above - https://youtu.be/kMoGa_DG8K4)

8. Pour the NaCl solution into a clean, dry 100 mL beaker if you have it. If your 100 mL beaker is not dry, then you will need to condition the beaker with the solution using three small, 3-5 mL, samples of the solution to rinse the entire inside of the beaker with the solution before pouring your solution into the beaker. Remember that this is a quantitative type experiment.

B. Measure the Density and Percent Composition of the NaCl Solution
(Video 4 Procedure/Skills 6 above - https://youtu.be/BPrBQ9PdMGs)

1. Record ✎ the mass of a 50 mL beaker, it does not necessarily need to be clean or dry.

2. Condition your pipette with the NaCl solution.

3. Deliver 10.00 mL using your pipette by delivering 2.00 mL of solution a total of five times into the 50 mL beaker. Be careful that the water level is as close as possible to the 2 mL mark, just like in the previous lab. It may help to tilt the beaker so that the depth of the solution is increased while pipetting. Record ✎ the mass the 50 mL beaker and the NaCl solution.

4. Repeat the measurements multiple times to determine increase your precision. The measurement in the previous step is "deliver 10.00 mL." Repeat the steps above two more times (for a total of three measurements) and record the results each time.

C. Dilute your NaCl solution from Part A to a known concentration
(Video 5 Procedure/Skills 9 above - https://youtu.be/6O7kjZFyhsU). This is commonly known as a serial dilution.

1. Condition your 50 mL graduated cylinder with distilled water. It should still be wet with distilled water when you are finished.

2. Add approximately 25 mL of distilled water.

3. Deliver 10.00 mL of your NaCl solution you prepared in Part A using your pipette. Do this by delivering 2.00 mL of the solution a total of five times into the 50 mL beaker. Be careful that the water level is as close as possible to the 2 mL mark, just like in the previous lab. It may help to tilt the beaker so that the depth of the solution is increased while pipetting.

4. Add distilled water until the graduated cylinder is filled exactly to the 50.0 mL line. Mix well without spilling (with inversion) until there are no swirlies. Do not add over 50.0 mL because you cannot take any of the diluted NaCl solution out of the graduated cylinder.

5. Pour the diluted NaCl solution into a clean, dry 100 mL beaker if you have it. If your 100 mL beaker is not dry, you will need to condition the beaker. To condition your beaker, rinse the inside of the beaker with the diluted NaCl solution using three small, 3-5 mL, samples of the diluted NaCl solution.

D. MEASURE THE DENSITY AND PERCENT COMPOSITION of the diluted NaCl solution 3 times:

1. Record ✎ the mass of a 50 mL beaker. It need not be clean or dry.

2. Condition your pipette with the dilute NaCl solution.

3. Deliver 10.00 mL using your pipette. Do this by delivering 2.00 mL of solution for a total of five times into the 50 mL beaker. Be careful that the water level is as close as possible to the 2 mL mark on your pipette, just like in the previous lab. It may help to tilt the beaker so that the depth of the solution is increased while pipetting.

4. Record ✎ the mass of the 50 mL beaker and the water.

5. Repeat the measurement multiple time to determine the precision. The measurement in the previous step is "deliver 10.00 mL." Repeat the above steps two more times (for a total of three measurements) and record the results each time.

E. Repeat the entire set of processes A-D changing the *5 g* of NaCl to approximately *3.5 g* of NaCl.

Calculations

A. Calculations for the Solutions

1. Calculate the mass of NaCl (subtraction).

2. Calculate the molarity of your NaCl solution
(Video 6 Procedure/Skills 10 above - https://youtu.be/lf48zzc16Sw)

    a. Convert grams of NaCl to moles of NaCl.
    b. Convert mL of solution in your graduated cylinder to L of solution.
    c. Remember that molarity is:

$$M = \frac{\text{mol of solute}}{\text{L of solution}} = \frac{moles\ NaCl}{Liters\ of\ solution}$$

3. Calculate the average and the standard deviation of the density of the NaCl solution.

    a. Calculate the mass of 10 mL of the solution (subtraction).
    b. The volume of your solution is 10.00 mL
    c. Remember that the density of a solution is defined as:

$$density\ of\ a\ solution = \frac{\text{mass of solution}}{\text{volume of solution}}$$

    d. Repeat this calculation for each of the three 10 mL trials. (Video 7 Procedure/Skills 11 above)
    e. Average the three values of density.
    f. Calculate the standard deviation of the three values.

4. Calculate the average and the standard deviation for the percent composition of the solution.

   a. Calculate the mass of the 10 mL of solution delivered using the pipette
   b. You know the mass of NaCl in your 50 mL graduated cylinder. You need to know the mass of NaCl delivered using the pipette. Use a scaling factor to calculate this:

$$\frac{10.00 \text{ mL pipetted}}{50.0 \text{ mL in grad cyllinder}} = \frac{\text{mass of NaCl delievered using pipette}}{\text{mass of NaCl in grad cylinder}}$$

   "Mass of NaCl delivered using pipette" is your unknown. Solve for it.
   c. Calculate the percent composition:

$$\% \text{ NaCl (m/m)} = \frac{\text{mass of NaCl delivered using pipette}}{\text{mass of 10 mL of solution}}$$

   d. Repeat this calculation for each of the three 10 mL trials. (Video 8 Procedure/Skills 12 above - https://youtu.be/5eS388xCdbg)
   e. Average the three values of percent composition.
   f. Calculate the standard deviation of the three values.

5. Calculate the concentration of a diluted solution. The dilution formula is:

   $M_1V_1 = M_2V_2$

   M_1 and V_1 are, generally, the molarity and volume of the more concentrated solution. You delivered 10.00 mL of your more concentrated solution (already calculated its molarity). You then diluted it to 50.0 mL in the graduated cylinder. (Video 9 Procedure/Skills 13 above - https://youtu.be/nWdGjettNF0)

B. Graphing by hand and using a spreadsheet program.

1. Please read the information about graphing data in the introductory materials prior to constructing your graph.

2. Good graphs use the total area of the paper to the greatest extent possible. Your graph and data must take up more than 75% of the graph paper on the page.

3. There is a sheet of graph paper at the end of this lab.

4. **GRAPHING BY HAND:** Label the vertical scale on the left, "Molarity (M NaCl)". Begin at 0.00 M and end at 2.00 M. Each square on your graph paper must be an even amount, such as 0.1 M, 0.2 M, or 0.05 M – not an odd amount like 0.1386 M. The graph paper at the end of this lab is 50 boxes tall by 50 boxes wide. A good choice for the y-axis would be to make the y-axis go from 0 to at least 2.00 M with each box representing 0.05 M.

   a. Label the horizontal scale on the bottom, "Density (g/mL)". Begin at 1.000 g/mL, and end at a value of 1.100 g/mL. The graph paper at the end of this lab is 50 boxes tall by 50 boxes wide. A good choice for Density would be to make the x-axis go from 1.000 to at least 1.100 with each box representing 0.002 g/mL.

   b. Plot your four data pairs for the four solutions of known salt concentration. (Video 10 Procedure/Skills 14 above - https://youtu.be/Bo1aWUjlemw)

   c. MAKING A BEST FIT LINE BY HAND: draw the best possible straight line through your four points. The best fit line will go as closely as possible through all four data points and DOES NOT have to go through the corner of your graph. With four points, the best fit line will have 1-2 points above the line and 2-3 points below the line and minimize the total distance between the line and the four data points. See your instructor for help if needed. (Video 11 Procedure/Skills 15 above - https://youtu.be/fDklGroiL4E)

5. **GRAPHING USING EXCEL:** Generate a similar graph using a spreadsheet program such as Microsoft Excel or Google Sheets. Be sure to print the equation for the line and the R^2 value on your graph. (Video 12 Procedure/Skills 16 above - https://youtu.be/5WdTyJJ4n9c)

6. Repeat steps 1 – 6 above for "% NaCl (m/m)" on the y-axis and "Density" on the x-axis using the four data pairs for the four solutions of known salt concentration. Choose the size of each box on the graph paper to be an even number. Keep the same x-axis as the previous graph.

Questions

1. Based on your graphs, what would the molarity be of a solution with a density of 1.025 g/mL?
    a. To do this:
        i. Graph by hand: draw a line that goes vertically from 1.025 g/mL until it crosses your hand drawn best fit line. From the point at which these two lines cross, draw a horizontal line to the left until it crosses the vertical scale. Using the point at which the line crosses the vertical scale, estimate the molar concentration of your unknown. Watch those sig figs! If each box on your graph is 0.05 M, then write your answer for the molarity to the nearest 0.01 M.

        ii. Graph in spreadsheet program: using the equation for the trendline, plug 1.025 g/mL in as the "x". Solve for "y". "y" is your molarity.

2. Based on your graphs, what would be the % NaCl (m/m) of a solution with a density of 1.025 g/mL?

Results

Table 1: Raw Data

Data	Mass of NaCl ≈ 5 g	Mass of NaCl ≈ 3.5 g
Temperature of the water		
Part A and B: Prepare a solution with a Known Concentration		
Mass of 50 mL grad cylinder		
Mass of 50 mL grad cylinder and NaCl		
Mass of 50 mL beaker		
Mass of 50 mL beaker and 10 mL solution		
Mass of 50 mL beaker and 20 mL solution		
Mass of 50 mL beaker and 30 mL solution		
Part C and D: Dilute a solution to a Known Concentration		
Mass of 50 mL beaker		
Mass of 50 mL beaker and 10 mL solution		
Mass of 50 mL beaker and 20 mL solution		
Mass of 50 mL beaker and 30 mL solution		

Last updated October 1, 2020

Table 2: Calculations

Calculations:	Mass of NaCl ≈ 5 g	Mass of NaCl ≈ 3.5 g
Part A and B: Prep a solution with Known Concentration		
Mass of NaCl		
Molarity of NaCl solution		
Average and standard deviation of the density of the NaCl solution		
Average and standard deviation of the percent composition of the NaCl solution		
Part C and D: Dilute to a Known Concentration		
Molarity of the diluted NaCl solution		
Average and standard deviation of the percent composition of the diluted NaCl solution		
Average and standard deviation of the percent composition of the diluted NaCl solution		