

## Experiment 1: Measurements

### Skills

- Measuring the mass and volume of a liquid
- Measuring the mass of a solid
- Calculating derived quantities
- Calculating regression lines
- Using regression lines to determine unknown quantities
- Completing calculations with significant figures

### Relevant Reading

Hein & Arena: 2.2–2.7 & 2.9

### Introduction, part 1

The density of a solution depends on how much matter is dissolved in it. Consider a bottle of syrup and an equally sized bottle of water? The sugar-rich syrup is heavier than the sugar-free water. In this lab, we will estimate the sugar content of a sports drink by analyzing the density of sugar solutions containing different masses of sugar.

### Introduction, part 2

#### *Uncertainty and Significant Figures*

Every measurement device used by scientists has its limits of measurement at which point it becomes uncertain. The last digit that can be read from a digital readout is always uncertain and we can assume that this digit is the uncertain digit in our measurement. Graduated devices have their last or uncertain digit between their calibration lines. For example, if the surface of a liquid falls between the lines for 1.1 and 1.2 mL, the hundredths digit should be approximated. If the surface appears to be exactly between the two lines, the volume, with significant figures, is 1.15 mL. Because of the uncertainty in the measurement process, we must properly express that uncertainty when we report measured quantities. We do so with the use of significant figures.

For example, if we measure a substance to have a volume of 2.7 mL and a mass of 3.823 g and calculate a density for this substance, our calculator gives the following answer:

$$3.823 \text{ g} / 2.7 \text{ mL} = 1.415 \text{ 925 9 g/mL.}$$

Note: density = mass/volume. What is the proper uncertainty in this answer? First let's look at the uncertainty of the measured quantities:

	Measurement	Uncertainty
Mass	3.823 g	0.001 g
Volume	2.7 mL	0.1 mL

Our calculator response gives an uncertainty reading of 0.000 000 1 g/mL, which depicts much greater accuracy than the measurements carried.

Whenever we conduct a calculation with significant figures, we must apply appropriate rules. For multiplication and division, the rule is that the answer has the same number of significant figures as the least significant number.

	Measurement	# of sig. figs.
Mass	3.823 g	4
Volume	2.7 mL	2

The volume measurement has the least number of significant figures. The calculated density must then have 2 significant figures: density = 1.4 g/mL.

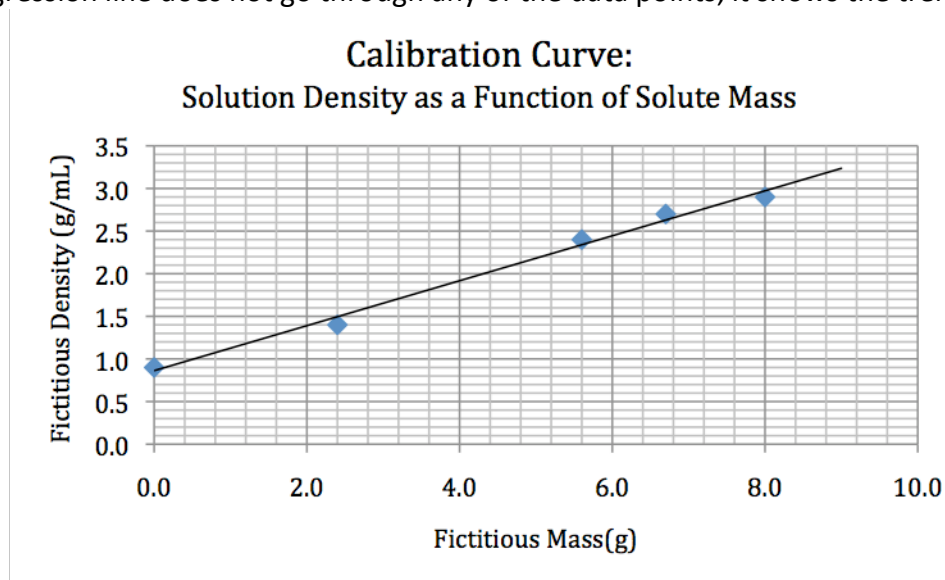
*Rules for Significant Figures:*

Review sections 2.3 and 2.4 of Hein & Morris for rules on identifying significant figures and keeping significant figures in calculations.

You will need to follow these rules for all calculations performed for this class.

### Calibration Curve

A calibration curve is used to determine a trend using known quantities. A linear calibration curve shows a trend that can be described with a straight line. A straight line follows the generic equation:  $y = mx + b$ , where  $m$  is the slope and  $b$  is the y-intercept. The y-intercept is the point at which the line crosses the y-axis. The regression line describes the general trend of data. Data points may not fall exactly on the line. Observe the example below. Even though the regression line does not go through any of the data points, it shows the trend.



- To use the calibration curve, we need to determine the equation of the line by
  - calculating the slope, and
  - determining the y-intercept.
- Determine the coordinates of the endpoints of the regression line.

Points for calculating slope

	x-coordinate	y-coordinate
Y-intercept	0	0.8
Point 2	8.4	3.2

- Calculate slope of regression line, where  $slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1}$

Example:

$$slope = \frac{rise}{run} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.8 - 0}{8.4 - 0} = 0.15$$

- Assemble the equation of the line. The y-intercept was determined in step 2 (the y-coordinate when  $x=0$ ). Plug in your calculated slope for  $m$  and the y-intercept for  $b$ .

Example:

$$y = mx + b = 0.15x + 0.8$$

$$y = 0.15x + 0.8$$

The calibration curve can now be used to determine the information about a sample with an unknown x-value of a sample with a known y-value. In the following example, the sample has a y-value of 2.0.

Example:

$$y = mx + b$$

$$y - b = mx$$

$$x = \frac{y - b}{m}$$

$$x = \frac{2.0 - 0.8}{0.15}$$

$$x = 8.0$$



Density Determination:

Repeat the following procedure for the solutions with 0, 1, 2, and 3 g of sugar. Skip steps 1, 2, 5, and 7 for the sample with no sugar.

1. Place a weigh boat on the milligram balance and tare the balance.
2. Mass out the appropriate mass of sugar. Record this mass to the nearest milligram (0.001 g).
3. Dry out your 50 mL graduated cylinder.
4. Mass the dry empty graduated cylinder.
5. Add the sugar to the graduated cylinder.
6. Fill the graduated cylinder with water until the volume is just less than 25 mL.
7. Stir the solution to dissolve the sugar and remove any air bubbles.
8. Use an eyedropper to add enough water to reach 25 mL. Record the volume to the nearest tenths of a milliliter (0.1 mL).
9. Mass the filled graduated cylinder and record the mass to the nearest milligram.
10. Calculate the density ( $d = m/v$ )

Table 1: Measurements of Sugar and Sugar Solution

Grey areas denote calculated values

Approximate Mass of Sugar (g)	Actual Mass of Sugar (g)	Volume of Sugar Solution (mL)	Mass of Sugar Solution (g)	Density of Sugar Solution (g/mL)
0				
1				
2				
3				

## Procedure

### Unknown Samples

Determine the density of a sample of a sports drink.

1. Dry out your 50 mL graduated cylinder.
2. Mass the dry empty graduated cylinder.
3. Fill the graduated cylinder with 25 mL of sample.
4. Mass the filled graduated cylinder and record the mass to the nearest milligram.
5. Calculate the density ( $d = m/v$ )

Table 2: Measurements of a Drink Sample

Grey areas denote calculated values

Drink	Volume of Drink (mL)	Mass of Drink (g)	Density of Drink (g/mL)
Sports Drink			

Name: \_\_\_\_\_

Lab Partner: \_\_\_\_\_

**Post-Lab****Results:**

Table 1: Measurements of Sugar and Sugar Solution

Grey areas denote calculated values

Approximate Mass of Sugar (g)	Actual Mass of Sugar (g)	Volume of Sugar Solution (mL)	Mass of Sugar Solution (g)	Density of Sugar Solution (g/mL)
0				
1				
2				
3				

Sample Density Calculation:

Table 2: Measurements of a Drink Sample

Grey areas denote calculated values

Drink	Volume of Drink (mL)	Mass of Drink (g)	Density of Drink (g/mL)
Sports Drink			

Density Calculation:



5. A student accidentally read the top, instead of the bottom, of the meniscus for all of her volume measurements.
  - a. Will her volume measurements be too large or too small?
  
  - b. Is this error systematic or random?
  
6. Why do we record values with the proper significant figures when we are analyzing laboratory results?
  
7. How many significant figures are in the measurement 0.001060 km?