

Lab objectives

Scientific knowledge

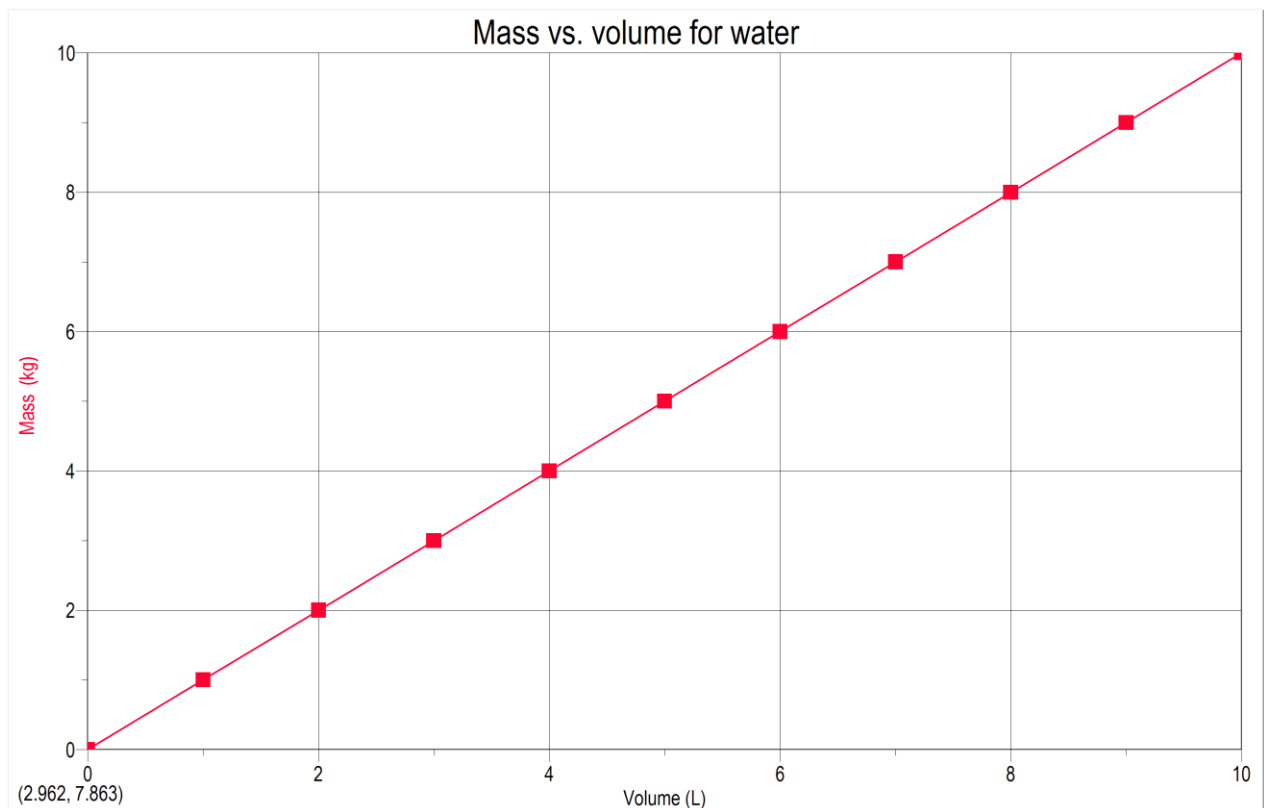
Students will demonstrate that as the volume of a substance increases, the mass increases proportionally. This proportionality is known as density.

Lab skills

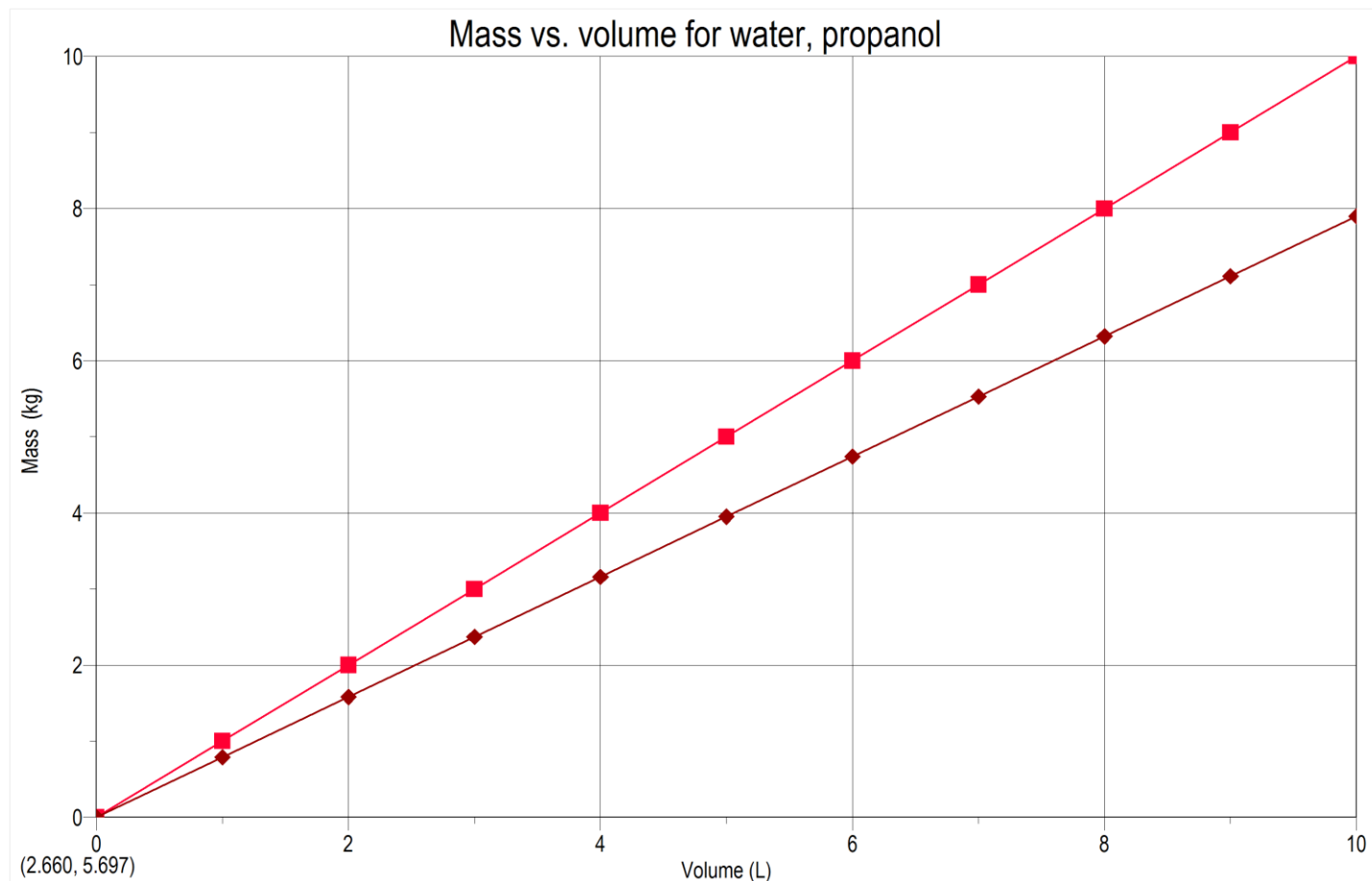
1. Students will use a spreadsheet to calculate values based on measurements made of various objects.
2. Students will use LoggerPro graphing software to find the slope of a line.
3. Students will demonstrate that using more precise measuring tools decreases the uncertainty of measured values and can increase the certainty of a conclusion.

Background

1.0 L of water has a mass of 1.0 kg. Of course, 2.0 L of water would have a mass of 2.0 kg. In other words, as if the volume of water is doubled, the mass doubles as well. Tripling the volume would triple the mass. In a situation like this, we say that the two values (in this case, volume and mass) are *directly proportional*. If we were to graph volume vs. mass of water, it would look like this:



Similarly, 1.0 L of propanol has a mass of 0.79 kg. If make graph of mass vs. volume for propanol and add it to the previous graph, we get:



Notice that the new data points also form a straight line, but the slope of the straight line is less than the slope of the line for water. Remember from algebra that slope is calculated as shown below:

$$Slope = \frac{\text{rise}}{\text{run}}$$

In this specific case, the rise is mass (look at the label of the y-axis) and the run is volume (look at the x-axis). So, for this data, the slope is:

$$Slope = \frac{\text{mass}}{\text{volume}}$$

Slope is a general term for the value of two directly proportional quantities. In the case of volume and mass, the slope is known as the *density* of the substance. We can therefore write the following mathematical formula:

$$Density = \frac{\text{mass}}{\text{volume}}$$

This means that in science, the slope of a line actually *means* something. In the science, when we calculate the slope of a line, we are actually finding the value of a measurable, physical quantity! The slope of a volume vs mass graph is the density of a substance.

Procedure

You will be given a set of twelve small cylinders made of the same material. You will need to find the volume of each cylinder. The volume of a cylinder is calculated by:

$$V_{\text{cyl}} = \pi r^2 l$$

In the equation above, r is the radius of the cylinder and l is the length of the cylinder. You will need to measure length and the diameter of each cylinder. You will also have to measure the mass of each cylinder with an electronic balance. In part I of the procedure, you will use a standard metric ruler and an balance that reads to the nearest 0.1g. In part II of the procedure, you will repeat the measurements using a Vernier caliper and a balance that reads to the nearest 0.001 g. Enter each measurement in the tables below.

Part I: Using a ruler and a 0.1g balance

Table 1: Length, diameter, and mass measurements

Description of material:	Cylinder #	Measured diameter, D (cm)	Uncertainty in diameter, ΔD (cm)	Measured length, L (cm)	Uncertainty in length, ΔL (cm)	Mass (g)	Uncertainty in mass, Δm (g)
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						

Part II: Using a caliper and a 0.001g balance, collect the following data:

Table 2: Length, diameter, and mass measurements

Description of material:	Cylinder #	Measured diameter, D (cm)	Uncertainty in diameter, ΔD (cm)	Measured length, L (cm)	Uncertainty in length, ΔL (cm)	Mass (g)	Uncertainty in mass, Δm (g)
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						

Part III: Making a spreadsheet of the data

Rather than make multiple calculations with a calculator, you will use a spreadsheet to make the calculations needed to find the density of the material. Your teacher will show you how fill in columns using formulas if you don't know how to do this.

Remember, any measurement has uncertainty. This means that the actual volume of each cylinder will fall within a range of numbers. In the same way, the measured mass will be within a range of values. Since the measured volume and mass of each cylinder is actually a narrow range of values, the density we calculate must also be a range. How do we find the maximum and minimum value for each density?

The greatest possible density calculation will happen if we use the largest possible mass value and the smallest possible volume value for each cylinder. This would be written mathematically as:

$$D_{\max} = \frac{\text{maximum mass}}{\text{minimum volume}}$$

Of course, the smallest possible density for each cylinder would be calculated by:

$$D_{\min} = \frac{\text{minimum mass}}{\text{maximum volume}}$$

The maximum mass value is found by adding the absolute uncertainty to the measured mass and the minimum mass value is found by subtracting the absolute uncertainty from each mass value. The maximum volume is

found by adding the absolute uncertainty to the radius and length measurements and calculating the volume. The minimum volume is found by subtracting the absolute uncertainty to the radius and length measurements and calculating the volume. A spreadsheet program will help us do these calculations very quickly.

Table 4: Maximum and minimum volume, mass data from Part I measurements

Cylinder #	Diameter, D	Length, L	Radius, r	Volume	ΔV	Max V	Min V	Mass, m	Δm	Max M	Min M
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

Table 5: Maximum and minimum volume, mass measurements from Part II measurements

Cylinder #	Diameter, D	Length, L	Radius, r	Volume	ΔV	Max V	Min V	Mass, m	Δm	Max M	Min M
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

Part IV: Graphing

1. Use LoggerPro to graph Max volume (x-axis) vs. Min Mass (y-axis) and Min volume and Max mass from part I. You may copy and paste the data from your spreadsheet into the LoggerPro data table. Use a separate data set for Max vol/Min mass and Min vol/ Max mass. Your graph will have two lines. Use the Analyze→ Linear fit functions to determine the slope of each line.
2. Using two more data sets, add the Max volume/Min mass and the Min vol/Max mass to your graph. Use the Analyze→ Linear fit functions to determine the slope of the line. You may copy and paste the data from your spreadsheet into the LoggerPro data table. Use a separate data set for Max vol/Min mass and Min vol/ Max mass. Your graph will know have four lines. Use the Analyze→ Linear fit functions to determine the slope of each line.
3. Print off all four graphs.

Questions

1. Compare the slopes of the two lines from the part I data. What is range of possible densities for the material (including units)?
2. Compare the slopes of the two lines from the part II data. What is range of possible densities for the material (including units)?
3. What do you notice about the range in #1 compared to the range in #2? Explain.
4. The cylinders were made of an element. Using a periodic table that includes the density of the elements, list all of the elements that fall within the range of values stated in #1.
5. The cylinders were made of an element. Using a periodic table that includes the density of the elements, list all of the elements that fall within the range of values stated in #2.
6. Did the lists change? If so, explain how and why the lists changed.