Density and Graphs

Equipment

You will need a millimeter ruler (read it in centimeters), your 50 mL graduated cylinder, a 10.00 mL volumetric pipette, and your 150 mL beaker.

Chemicals

Water, a metal cylinder, unknown metal shot, and an unknown salt solution.

Introduction

When there are two variables that are linked to each other so that if we plot one of the variables against the other we get a straight line, we say that there is a linear relationship between the two.

One such relationship is that between the mass of a substance and the volume occupied by that substance.

The property called density describes this relationship. The equation that describes density is:

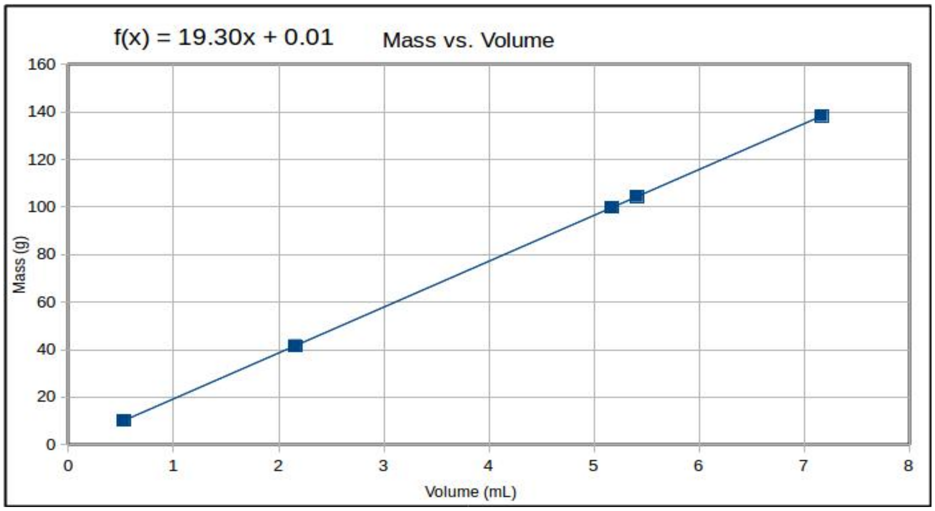
$$d=\frac{m}{v} \quad \textbf{(Equation 1)}$$

where “d” stands for the density of an object, “m” stands for it's mass, and “v” stands for the volume occupied by that object.

For example, if we graph the following experimental data:

Mass (g)	Volume (mL)
10.2	0.528
41.7	2.16
99.8	5.17
104.4	5.41
138.3	7.17

with the mass on the y-axis and the volume on the x-axis it looks like this:



We can see that there is a linear relationship between mass and volume here because we can draw a straight line through the points on the graph. This is called the best-fit straight line.

The equation for any straight line looks like this:

$$y = mx + b$$ **(Equation 2)**

Here "m" represents the slope of the line and "b" represents the y-intercept. For our line, m = 19.30 and b = 0.01. Look at the equation next to the title. f(x) is another name for y.

The slope is:

$$\text{slope} = \frac{\text{Rise}}{\text{Run}} = \frac{y}{x} = \frac{\text{Mass (g)}}{\text{Volume (mL)}}$$ **(Equation 3)**

But mass over volume is density (see Equation 1), which tells us that the slope of the best-fit straight line in a graph of Mass vs. Volume is the density.

If we needed to find the volume occupied by a certain mass of the substance we made the graph for we would use the equation of the best-fit straight line. Lets say we need to know the volume occupied by 50.0 g of this substance. We would solve for x and replace f(x) (which is y) with 50.0 g:

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

or **(Equation 4)**

$$x = \frac{50.0\,g - 0.01\,g}{19.30\,g/mL} = 2.59\,mL$$

Procedure

Part A (Density of a cylinder)

Obtain a metal cylinder and write down the number scratched on it's end:

Metal cylinder number:______________(A1)

Using a millimeter ruler measure its length in **centimeters.**

Length of metal cylinder:______________(A2)

Using the same ruler measure the diameter of the metal cylinder in centimeters.

Diameter of metal cylinder:_____________(A3)

Measure the mass of the same metal cylinder on the balance recoring it's mass in grams to 3 places to the right of the decimal.

Mass of metal cylinder:_____________(A4)

Part B (Density of metal shot)

Obtain an unknown metal shot from the stockroom. Write down the unknown number:

Unknown metal shot number:____________(B1)

Place a beaker on a balance and tare the balance. With the balance tared (it should read 0.000 g with the beaker on it) add all of your unknown metal shot to the beaker, place it back on the tared balance, and record the mass of your unknown metal shot.

Mass of metal shot:____________(B2)

Fill your 50 mL graduated cylinder about half full of tap water. Record the volume of water in the graduated cylinder to the correct number of significant figures.

Initial volume in graduated cylinder:____________(B3)

Being careful not to splash any water out of the graduated cylinder add all of your metal shot to the water in the graduated cylinder. Carefully tap it on the bench a few times to release any trapped air.

Read the new volume of water in the graduated cylinder with the metal shot added.

Final volume in graduated cylinder:____________(B4)

Part C (Mass percent sodium chloride in an unknown solution)

Obtain an unknown salt solution from the stockroom and record it's unknown number.

Unknown number of salt solution:_____________(C1)

Place a clean, dry, beaker on a balance and tare the balance (the balance should read 0.000 g with the beaker on it).

Remove the beaker, being careful not to lose the tare.

Using a 10.00 mL volumetric pipette add 10.00 mL of your unknown salt solution to the beaker and place the beaker carefully back on the same tared balance.

Record the mass of 10.00 mL of your unknown salt solution to 3 places past the decimal.

Mass of 10.00 mL of unknown salt solution:_____________(C2)

Data and Analysis

Part A Data:

Metal cylinder number:______________(A1)

Length of metal cylinder:______________(A2)

Diameter of metal cylinder:_____________(A3)

Mass of metal cylinder:_____________(A4)

Part A Analysis:

1.) Calculate the volume of your metal cylinder using the formula for the volume of a cylinder and record it on the line below to the correct number of significant figures with the correct units.

$$V_{cylinder} = \pi r^2 h$$

$$r = \frac{\mathbf{(A3)}}{2} \; ; \quad h = \mathbf{(A2)}$$ **(Equation 5)**

where r is the radius of the cylinder and h is the height of the cylinder (both should be in cm). Remember radius = diameter/2.

$$r = \frac{d}{2}$$ **(Equation 6)**

Volume of cylinder: ______________(A5)

2.) Calculate the density of your metal cylinder using **Equation 1**. Here m = **(A4)** and V = **(A5)**. Record the density on the line below to the correct number of significant figures with the correct units.

Density of metal cylinder:_____________(A6)

Part B Data:

Unknown metal shot number:____________(B1)

Mass of metal shot:____________(B2)

Initial volume in graduated cylinder:____________(B3)

Final volume in graduated cylinder:____________(B4)

Part B Analysis:

3.) The volume of your metal shot is how much the volume in your graduated cylinder increased when you added the metal shot to it. That is, the volume of your metal shot is the final volume minus the initial volume in your graduated cylinder.

$$V_{shot} = (\mathbf{B4}) - (\mathbf{B3})$$ **(Equation 7)**

Use Equation 7 to calculate the volume of your metal shot and record it on the following line to the correct number of significant figures with the correct units.

Volume of shot:______________(B5)

4.) Now calculate the density of your metal shot using **Equation 1** where the mass is **(B2)** and the volume is **(B5)**. Record this density on the following line to the correct number of significant figures and with the correct units.

Density of shot:_______________(B6)

5.) Using the following table determine the identity of your unknown metal shot. The metal that has its density closest to the density you calculated for **(B6)** should be your metal. Record the identity of your unknown along with it's unknown number **(B1)** on the line below.

Metal	**Density**
Aluminum	2.70 g/cm^3
Lead	11.34 g/cm^3
Nickel	8.908 g/cm^3
White Tin	7.365 g/cm^3
Gray Tin	5.769 g/cm^3

Unnown Number:_______________(B1)

Identity of unknown:_______________(B7)

Part C Data:

Unknown number of salt solution:_____________(C1)

Mass of 10.00 mL of unknown salt solution:_____________(C2)

Part C Analysis:

6.) Calculate the density of your unknown salt solution using **Equation 1**. Here m = **(C2)** and V = 10.00 mL (4 significant figures!). Record the density of your unknown salt solution on the following line to the correct number of significant figures. Make sure to include the correct units.

Density of unknown salt solution:________________(C3)

7.) Using Excel (or LibreOffice Calc) make a graph of the following data points plotting density on the y-axis and mass % sodium chloride on the x-axis. Include the equation of the best-fit straight line. Staple the graph with equation on it to this report.

Here is a video showing how to use LibreOffice Calc to make this graph.

Mass % Sodium Chloride	**Density (g/mL)**
0.00	0.9960
3.50	1.023
5.25	1.036
8.75	1.063
11.25	1.082
14.50	1.107
16.75	1.124
19.00	1.141
23.50	1.175
27.25	1.204

8.) Use the equation of the best fit straight line to solve for x (the mass % sodium chloride) for your unknown using the density of your unknown **(C3)** as your y-value. See **Equation 4** where y = **(C3)**, m is the number in front of “x” in your best-fit straight line equation, and b is the number after the “+” in your best-fit straight line equation.

Record the mass % sodium chloride in your unknown and your unknown salt solution number **(C1)** on the following line.

Unknown number of salt solution:_______________(C1)

Mass % sodium chloride unknown salt solution:_______________(C4)