Lab: Graphing Density

FOR THE TEACHER

Summary
In this lab, students will collect data and then use graphing to determine the density values of unknown metal samples.

Grade Level
High School

Objectives
By the end of this lab, students should be able to
- properly construct a line graph using Excel.
- include a linear equation for a line graph in Excel.
- analyze a linear equation (slope-intercept form) and determine a physical quantity (density) from that equation.

Chemistry Topics
This lesson supports students’ understanding of
- Density
- Physical Properties

Time
Teacher Preparation: 1 hour
Lesson: 2 hours (2 class periods - 1 for actual lab completion, the next for Excel graphing)

Materials
- 50-mL graduated cylinders
- metal shot samples; options can include (but aren't limited to) copper, aluminum, steel, and nickel
- scoops/spoons (for transferring metal shot pieces)
- balance (digital works best)
- 100-mL beakers

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- When students complete the lab, instruct them how to clean up their materials and dispose of any chemicals.

Teacher Notes
- I typically do this towards the beginning of the year with my first-year students as we are discussing measurement, representing data, and significant figures. I do expect them to record data with proper significant figures and then to use those digits correctly in their calculations.
Prior to doing this lab I have a day of reviewing how to set up line graphs using experimental data. We go through the calculation of slope (by hand, without a computer doing it for them).

I find that this is a very challenging lab for my students for a couple of reasons:
- First of all, they are not used to actually using line graphs to represent something beyond simplistic x & y coordinates.
- Secondly, they come in with a very superficial understanding of slope; with some prodding they can regurgitate the formula but most students do not really understand what it is telling them.

I have the students find densities of metals at the end of this lab, but that could certainly be done ahead of time by having students look them up and then discussing how close those densities are to each other, which ones would float vs. sink, and comparing which metals would be heavier for a given volume.

The metals are “unknown” in identity to the students, so you will need to label them with a number or letter for students to use in their data table, and keep a key for yourself.

It would be helpful to review the procedures with your students before starting the lab.

A great alternative/extension was given to me by a colleague: use copper-colored bee-bees instead of pure metals and have students determine if they are really copper based on their density (which should most definitely show that they aren't copper). A discussion of how we reach a conclusion when information (physical appearance) appears to be in conflict would be appropriate in this case!

Cross-Disciplinary Extensions

Connect to Math
- Students are involved in graphing and interpreting the slope(s) of the graphs
- Students also use simple algebra to find the percent error of their values from the accepted values

Connect to Reading
- One of the research questions requires students to look up additional information, interpret it, and compare it to their own results. Students will need to pay particular attention to the units involved in their researched results and make sure that those units are valid compared to what they found.

Connect to Writing
- Students prepare their results as part of a lab report that includes the following sections: purpose, data (including a properly presented data table), calculations/analysis (including their graphs), conclusions, and follow-up/extension questions.

Connect to Social Studies
- Once the metals are identified a follow-up activity could be to have students find out how the metals are used. They could also look up how these metals are obtained and the environmental impact that is caused by the mining used to get them. If aluminum is used it can be very eye-opening for the kids to research the cost of getting aluminum from its ore versus the cost of recycling it.
  - This 2012 article is filled with very applicable information regarding the connection between mining and recycling of various metals.
  - Here is the EPA information page regarding aluminum and its recycling.
FOR THE STUDENT

Lesson

Graphical Analysis of Density

Background
The study of chemistry involves both observing matter’s properties as well as its changes. This nearly always involves a numerical measurement of the changes in those properties.
The purpose of this lab is to experimentally determine the densities of two different metals using graphical analysis. By now, the formula for calculating density should be quite familiar to you. In this lab, however, a graphing technique will be used rather than a single calculation. By plotting the mass versus volume for a series of different amounts of the metal, a line graph can be drawn. The slope of this line has units of grams per milliliter, also known as density! This method is useful because it allows us to get an average of many different data points without having to repeat each individual measurement multiple times.

Materials
- Electronic balance
- 100-mL beaker
- scoop
- 50-mL graduated cylinder
- Unknown samples of metal
- Water

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Upon completion, water can be emptied into the sink and metals can be dried and returned to their original container.

Procedure
1. There are several metals available on the front counter. You will use two of these in your experiment. Make note of the appearance and the ID numbers for the two samples that you intend to use in the provided data tables.

2. Fill your beaker approximately ¼ full with the first sample of metal from the front counter (make sure that you know which one you have!).

3. Fill your graduated cylinder to 20.0 mL with tap water. Record the exact volume of water ($V_1$ for all data points) in the first data table by reading the hash marks on the graduated cylinder.

4. Then place the cylinder containing water on the electronic balance (don’t forget to zero the scale first). Record the total mass in the data table ($M_1$ for all data points).
5. In order to collect data for the first row in the data table, carefully drop pieces of metal into the cylinder until the water level rises to around the 25.0 mL mark. Record this exact volume in the data table for \( V_2 \). Calculate \( (V_2 - V_1) \) the volume of the metal only based on water displacement and record this in the data table.

6. Return to the balance and determine the mass of the cylinder, water, and metal combination. Record this mass as \( M_2 \) in the data table. Calculate \( (M_2 - M_1) \) the mass of just the metal and record this data.

7. The first row of the data table should now be complete. You will continue to add metal to this graduated cylinder, do not remove the water or metal from it!

8. Data point 2: Continue to add more of the same metal to the graduated cylinder until the water level reaches around the 30.0 mL mark. Record this exact volume in the data table for \( V_2 \). Calculate \( (V_2 - V_1) \) the volume of the metal only based on water displacement and record this in the data table.

9. Return to the balance and determine the mass of the cylinder, water, and metal combination. Record this mass as \( M_2 \) in the data table. Calculate \( (M_2 - M_1) \) the mass of just the metal and record this data.

10. Repeat steps 8 and 9 in order to complete row 3 and 4 in the data table. For data point 3 add the same metal until a volume of approximately 35.0 mL has been reached. For data point 4 add the same metal until a volume of approximately 40.0 mL has been reached.

11. Repeat steps 2-10 for one of the other two metals. Report your data in the second data table provided. Once you are done be sure to clean up your work area!

Data

<table>
<thead>
<tr>
<th>Metal Sample ID# _____</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Point</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>
4

Appearance of metal:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Volume: Water ($V_1$)</th>
<th>Volume: Water &amp; Metal Only ($V_2 - V_1$)</th>
<th>Mass: Water &amp; Cylinder Only ($M_2 - M_1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
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<td>4</td>
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</tbody>
</table>

Appearance of metal:

**Analysis**

The first two analysis questions will be done tomorrow using Excel. If you are not familiar with using Excel to set up tables and graphs then be sure to see your instructor for help!

1. Set up a table in Excel with the data points for volumes and masses from the “Metal Only” columns in your data table for one of your tested metals (place volume on the x-axis and mass on the y-axis). Use this data to have Excel set up a scatter plot. Once plotted have Excel insert a trend line (called a "best fit line" in math) and include the linear equation that describes the line. Edit your graph to include proper labels and units for the x-axis and the y-axis. Also be sure to give the graph a proper title.

2. Repeat analysis question #1 for your second metal sample. If you are confident with your Excel skills then you can set it up so that both metal samples show up on the same graph.
3. The trend line label should be showing the line's equation in \( y = mx + b \) form. Recall that the slope of a line is the "rise over the run", which is better expressed as the change in two \( y \) values divided by the change in their corresponding \( x \) values. Since these two graphs have units of grams on the \( y \)-axis and mL on the \( x \)-axis, the slope will have units of g/mL (density!). Report the slopes of each of your lines as your experimental densities with appropriate significant figures and units included.

4. Research: There are quite a number of elements that are classified as metals. Use appropriate sources to look up the accepted densities of the following metals: lithium, aluminum, nickel, copper, zinc, silver, gold, and lead. Based both on your calculated densities and your observations about the appearance of each sample you should be able to make a prediction as to the identity of each metal sample. Find the percent errors for your values compared to the accepted values of the metals you think you had.

5. Analyze the following errors and explain how they would affect the final densities (or if they would have no effect). Do not just say that they "would throw things off"; be specific as to whether these errors would give final densities that are too high, too low, or unchanged and explain why these errors would cause that result.
   a) Air bubbles are trapped between the metal pieces when they are dropped into the graduated cylinder.
   b) The outside of the graduated cylinder was not dried before the initial massing (you may assume that the same amount of excess water was present on the outside of the cylinder throughout the entire experiment).