

A Penny for Your Thoughts: Scientific Measurements and Introduction to Excel

Pre-lab Assignment:

Reading:

1. Chapter sections 1.4-1.6 in Brown, LeMay, Bursten, and Murphy.
2. This lab handout!

Questions:

1. What is the density of an object with a mass of 1.65 g and a volume of 0.18 mL?
2. Three trials of an experiment give you values of 14.7 s, 14.6 s, and 14.6 s. If the literature offers an accepted value for this experiment of 15.9 s, were your data accurate? Precise? Explain, and briefly speculate on what aspect of your experimental measurement would most likely need to be changed for you to obtain better results.

Introduction

In this experiment you will explore scientific measurements, including measuring mass with a balance, volume by water displacement, and errors in measurements. You will also learn to determine densities and use this information to find out the percentage of copper and zinc in a US penny. Along the way you will learn to use Excel—a powerful spreadsheet program that you will find extremely useful throughout your Colby career. Make sure you learn the Excel skills covered in this experiment as they will be encountered in future labs when you are working alone.

Percent Composition of Zinc and Copper in US Pennies

The current US penny is made of metallic copper plated onto a zinc core. You are going to determine the density of pure copper and zinc metals as well as the density of pennies. From this data you will estimate the percentages of copper (Cu) and zinc (Zn) in pennies.

In an object composed of multiple materials (like a penny), the density is a weighted average of the densities of the pure substances that make up the object. If the density of pure copper is d_{Cu} and the density of pure zinc is d_{Zn} , then the density (d) of a composite of copper and zinc is (p = the % Cu by mass and q = % Zn by mass):



$$d = \frac{p d_{\text{Cu}} + q d_{\text{Zn}}}{100} \quad (1)$$

Since pennies contain only copper and zinc: $p + q = 100\%$ and therefore $q = 100-p$:

$$d = \frac{p d_{\text{Cu}} + (100-p) d_{\text{Zn}}}{100} \quad (2)$$

If we know the % copper (p), we can solve for d. On the other hand, if we know the density of the composite (d), we can use equation 2 to obtain the % copper (p) in the sample.

Procedure

1. *Density of Cu, Zn, and Pennies:* Working with your assigned group, each group member will choose & measure the assigned sample (either zinc, copper, or pennies). As a group you will choose three different types of the assigned copper or zinc, or measure three different sized piles of pennies. Your group will then share this data with other groups. Your group also needs to acquire data from other groups for the two sample types left unmeasured.
2. Your data set needs the following to be complete: three different types¹ of copper, three different types of zinc, and three different samplings of pennies (choose a different number of pennies for each sampling).
3. Each partner will measure the mass of her/his sample on a balance (always protect the pan of the balance with a tared piece of weighing paper, weigh boat, or a beaker). Always record the balance number you are working on when you record mass data into your notebook.
4. To determine the volume: use a graduated cylinder with enough water to fully submerge the chosen sample. After recording the initial volume (read between the calibration marks on the graduated cylinder to obtain an extra significant figure), carefully slide the sample of metal into the cylinder. Tap the side of the cylinder to dislodge air bubbles adhering to the surfaces of the metal pieces. Record the new volume. Record all data in a table in your notebook as you make measurements. Ensure that the displaced volume of each sample is sufficient to obtain *at least 2 significant figures*. WHY?
5. Enter your measurements in Excel using the general instructions given below as needed. If you print or view online the Excel Primer handout available on the lab web page, you will find more detailed instructions for how to use Excel. Keep in mind that you want the copper data together, the zinc data together and the penny data together....essentially three tables on one spreadsheet. You want to put the type of object measured in the first column. The second column will be the mass of the object (you can denote grams with “g”). The third and fourth columns are for your volume before and after displacement (you can denote milliliters with “mL”). The fifth column will be used to calculate the change in volume. To do this you will enter a formula in the top cell of this column, and then copy the formula down the column where applicable. **Always record the specific formula(s) used to create Excel spreadsheets & graphs, directly into your lab notebook.** The sixth column will be used to calculate the density of the object². Click on an empty cell to be labeled “Average”. Click on the cell next to it and use the function key or =AVERAGE() function to have Excel automatically calculate the average density value. Now click on another empty cell that can be labeled “Standard Deviation”. After clicking on the empty cell next to this, you can again use the function key or the =STDEV() function to automatically find the value you want. In order to find how much error your data set has, in terms of precision, you next need to calculate the % relative

¹ Be sure to select enough of each substance to make a meaningful measurement. For example, a single copper wire is not likely to displace a significant amount of water.

² Density equals mass/ volume (g/mL).

standard deviation. Please refer to the Error Analysis handout on the laboratory website. Be sure to show your calculation for this value in your lab notebook. You can now determine your precision for this data set. The %precision equals 100% minus the % relative standard deviation. You will want to know the Average, the Standard Deviation, the Relative Standard Deviation and the Precision for your copper data, your zinc data, and your penny data.

An example Excel table for one of the metals might look like this:

objects	mass (g)	Volume before (mL)	Volume after (mL)	Volume object (mL)	d (g/mL)
nails	32.3454	23.2	26.8	3.6	8.863
bars	38.4567	25.6	29.9	4.3	8.985
rods	44.3245	19.5	24.5	5.0	8.792
				average=	8.92025
				st.dev=	0.1132825

6. Composition of the pennies: In your lab notebook, solve Equation 2 for the percent Cu (p). Then use Excel to calculate the percent copper of pennies from the calculated average densities of pure copper and pure zinc that you measured.

7. Plot of the Density of Cu/Zn Composites verses Composition: You will now create a graph that correlates the density of a Cu & Zn composite to the percent Cu present. It should come as no surprise that this plot will be a straight line, since Equation 2 is linear in the p variable. But, this will be a good beginning exercise to get to know Excel better. When graphing, Excel reads the first column as the x-variable, therefore enter the percent Cu in column 1 (see Figure 1). Here is a really useful tool; when you want to enter a series of values down a column such as 0,10,20,30,etc.; you only need to enter the 0 and the 10. Then you highlight these two cells, click on the small box in the lower right corner of your highlighted area, and then drag the mouse down the column. This action automatically fills a column with the correct values (you now see the next value as 20, then 30, etc.).

The second column will be the y-variable, which is the density of pennies with known copper/zinc compositions, d. Use Excel to calculate the density of the composite based on your experimental averages for Cu and Zn using equation 2. If you write a formula in the top cell you can use Excel to copy the formula quickly down the entire column. Ask for help if you don't know how to do this. You will need to use absolute cell addresses for the Cu and Zn densities (see Excel Primer).

p % Cu	Density (g/mL)
0	
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Figure 1: Example table

Now that you've created the table you are ready to make the graph. The [Excel Primer](#) gives directions for making a graph if you have not used this software before. An example plot is shown in Figure 2.

DENSITY OF PENNIES AS A FUNCTION OF THEIR COPPER CONTENT

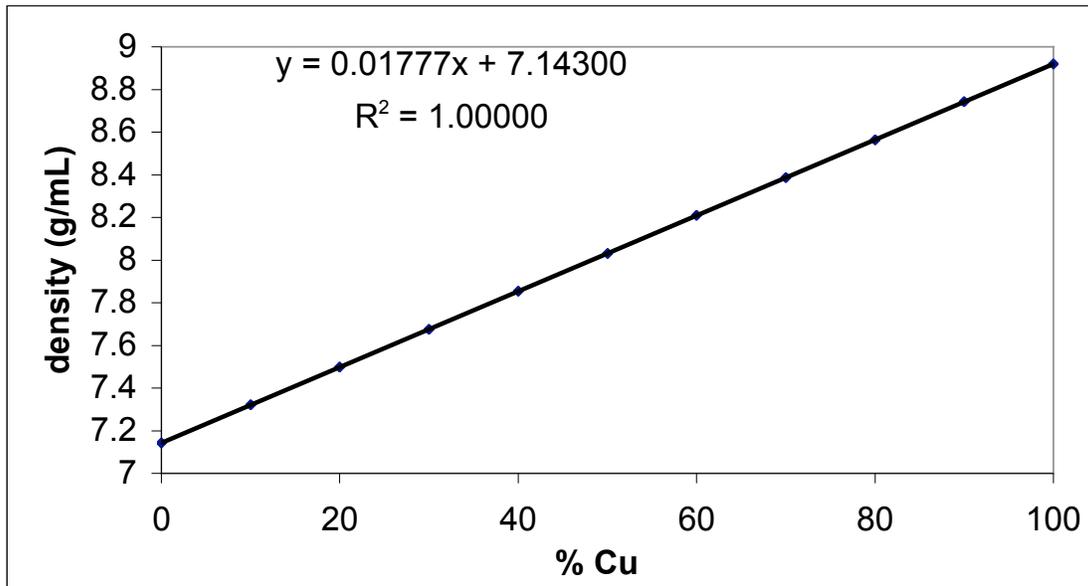


Figure 2: Example plot

Add a linear trend line and place the regression result on your graph as shown above. Also, extend the number of significant figures in the slope and intercept. Ask for help if you need it, but first try using the Excel Primer. Print out your Excel work and tape it into your laboratory notebook.

What should be in your lab notebook now?

1. The calculation for the % Cu in pennies, with the proper number of significant figures to be reported, should be shown.
2. Give the literature values for the density of Cu and Zn. Cite your literature source. Find % Cu of currently circulated pennies. Cite your literature source.
3. Calculate the % relative standard deviation, and the % relative experimental error for your Cu density. For further guidance go to Error Analysis link. Your precision will be 100% minus the % relative standard deviation. Your accuracy will equal 100% minus the % relative experimental error. Repeat the calculations for the Zn density, and then the penny density.

What should be attached to your discussion now, but put into your lab notebook later?

1. The three Excel tables for the calculation of the density of Cu, Zn, and the pennies. The tables should include the average and standard deviation of the trials. Always show one example calculation for each type of variable you determined. All values should be reported with proper significant figures.
2. The Excel table and graph for the Density versus % Cu. The graph should be at least a third of a page with a title (“y” vs. “x”), labeled axes that include units, and the linear regression curve fit results, with expanded numbers of significant figures.

What should be in your Discussion?

Your discussion should be on one page (maximum!) and typed. Any reported values should have proper significant figures in a discussion. The best approach to starting a discussion is to:

1. Open with a clear statement of what your objective was for the experiment.
2. Lead into the key results you obtained and discuss the significance of each as applicable (this is the bulk of the discussion). If comparing experimental results to literature values, report both values and discuss discrepancies.
3. This naturally leads into reporting experimental error values (for example, % relative standard deviation, % relative experimental error, % precision, and % accuracy). The significance of these values needs to be explained.

Note: There will be systematic error for all experiments, but in many cases when obvious and/or possible it will be corrected. The error of most concern in a discussion is usually the random error, which occurs and can't be corrected. Try to give brief but reasonable explanations of the most significant possible source(s) of random error. Writing about errors such as misreading a thermometer or a piece of glassware is not that helpful to a discussion. Think harder. What really may have caused the experimental value to be greater than or less than the literature value? How does that deviation affect your interpretation of the results (maybe it doesn't)? It is better to write a thorough discussion of one significant source of error than to just name five errors. In this experiment, it is possible that there may be very different types of error at play for the copper versus the zinc density. Therefore, try to be too general when explaining sources of error.