

## Experiment 1: Scientific Measurements and Introduction to Excel

**Reading:** Chapter 1 of your textbook and this lab handout.

### Learning Goals for Experiment 1:

- To use a scientific notebook as a primary record of procedures, data, observations, and example calculations
- To make scientific measurements
- To become familiar with Excel to tabulate, calculate, analyze, and graph scientific data
- To evaluate the uncertainty (error) in scientific measurements, and understand the causes of the underlying uncertainty
- To present your formal results through a laboratory report along with proper citations

### 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.

*Throughout this laboratory you will need to organize and analyze data in Excel. Always make a printed copy of everything you do in Excel to attach in your lab notebook.*

### 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  $d_{\text{Cu}}$  and the density of pure zinc is  $d_{\text{Zn}}$ , then the density ( $d$ ) of a composite of copper and zinc is:

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

In this equation,  $p$  = the % Cu by mass and  $q$  = % Zn by mass. Since pennies contain only copper and zinc:  $p + q = 100\%$  and therefore  $q = 100 - p$ . So equation 1 may be rewritten as:



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

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:** You will work in groups of three. One partner will work with three different types of copper, another with three different types of zinc, and the third with three different samples of pennies. Each partner will measure the mass of her/his samples on a balance (always protect the pan of the balance with a tared piece of weighing paper or weigh boat). Always record the balance number you are working on when you record mass data into your notebook.

To determine the volume of your metal pieces and penny samples: 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 raw 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*.

Enter your measurements in tables in Excel using the general instructions given below. 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. Create three tables on your spreadsheet, one for each metal and a third for the pennies. 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 object.<sup>1</sup> 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 % error. Please refer to the **Error Analysis** handout. Be sure to show your calculation for this value in your lab notebook. You can now determine the % precision for this data set, which is simply 100% minus the % error. You will want to know the average, the standard deviation, the standard deviation of the mean, % error, and the precision for your copper, zinc, and penny data.

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

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<sup>1</sup> Density equals mass/volume (g/mL).

objects	mass (g)	Volume before (mL)	Volume after (mL)	Volume object (mL)	d (g/mL)
nails	32.3454	23.20	26.80	3.60	8.98
bars	38.4567	25.60	29.90	4.30	8.94
rods	44.3245	19.50	24.50	5.00	8.86
				Average	8.93
				SD	0.06
				SDOM	0.03
				% Error	0.3
				% Precision	99.7

**2. Composition of the pennies:** In your lab notebook, solve Equation 2 for the percent Cu (p). To do this, refer to your Excel sheet and use the average densities that you obtained for pure copper, pure zinc, and the pennies.

**3. Plot of the Density of Cu/Zn Composites vs. 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 trick; 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 the copper/zinc composite, 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 of Cu/Zn composite(g/mL)
0	
10	
20	
30	
40	
50	

**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 Cu/Zn COMPOSITE AS A FUNCTION OF Cu CONTENT

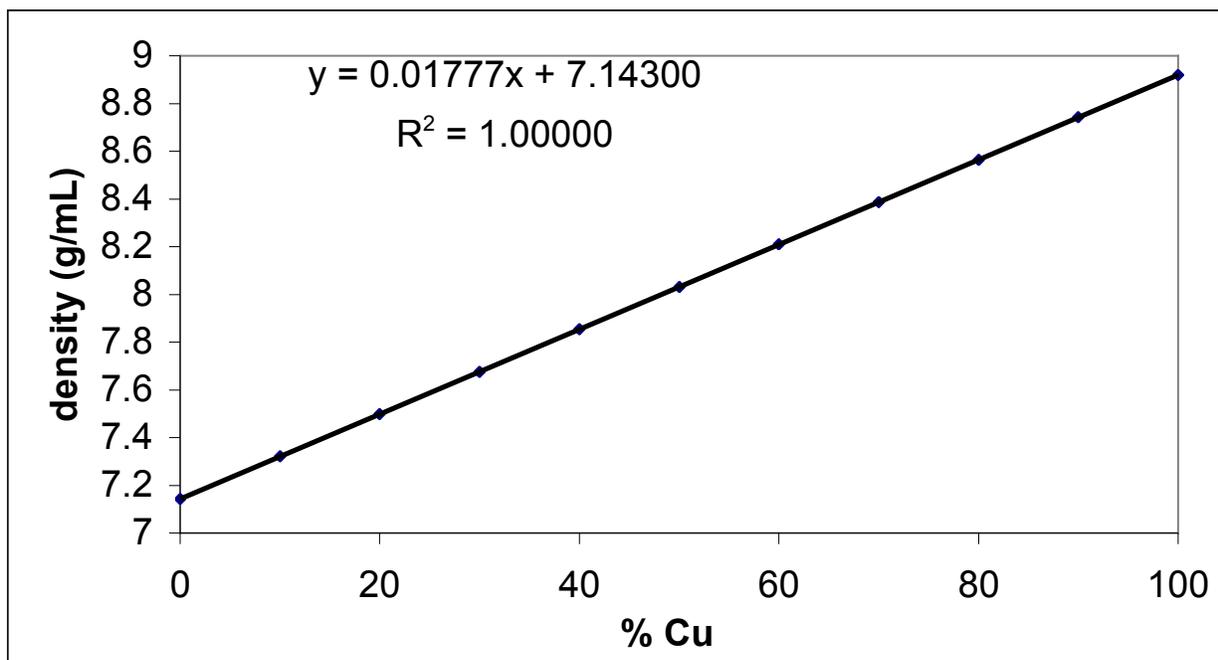


Figure 2: Example plot

Add a linear trend line and place the regression result on your graph as shown above. Please also do a LINEST analysis as outlined in your **Error Analysis** handout. The table and graph should be used in your lab report (see below). Please do not attach these to your notebook until after they have been graded and returned to you.

4. Using the average penny density that you determined experimentally, and the equation for the line in your graph, determine the % composition of Cu and Zn in the penny. Record these percentages in your notebook and compare your results to the literature values.

5. *Save your data to the fileserver:* Information on saving data to the file server will be provided by your lab instructor.

6. Print your Excel data tables to include in your notebook. Also print your % Cu vs. density graph, along with the associated data table.

7. Look up literature values for the density of Cu and Zn. Make sure to cite your literature source(s). In addition, find the % Cu of currently circulated pennies. Again, remember to cite your literature source.

**What should be in your lab notebook (in addition to title, purpose, procedure, observations, etc.)?**

1. Attach the three Excel data tables for the calculation of the density of Cu, Zn, and the pennies. The tables should include the average, standard deviation, standard deviation of the mean, and % error of the trials. Always show one example calculation in your notebook for each type of variable you determined. All values should be reported with proper significant figures.
2. The calculation for the % Cu in pennies, with the proper number of significant figures to be reported.
3. The literature values for the density of Cu, the density of Zn, and the % Cu of currently circulated pennies. Remember to cite your literature sources.

**Laboratory report:** Use the **Report Form** for Experiment 1.