Chemistry 123

THE NICKEL EXERCISE

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Western Washington University

INTRODUCTION

Recall that *precision* refers to the closeness of a set of values obtained from identical measurements of a quantity, whereas *accuracy* is defined as the closeness of a single measurement to the *true* value. In most experimental work, it is easy enough to determine the precision of a set of measurements simply by repeating the measurement several times. Generally the accuracy of those measurements is unknown; after all, if we knew the true value of the measurement, we would be spared the bother of doing the experiment at all. In the exercise below, however, we will have the unusual situation in which the true value is assumed to be known.

The exercise to be completed involves a series of weighings using the Mettler AE 100 analytical balances. These balances have a capacity of about 100 grams and measure mass to ± 0.1 mg (± 0.0001 g). As with any precision instrument, care is required:

- never put chemicals directly on the balance pan

- always place objects on the pan gently

- be sure objects to be weighed are at room temperature

- do not lean or place objects on the balance table

- be sure all doors are closed when making final mass readings

- keep the balance area neat and clean for other students

When several samples are needed for an analysis, weighing *by difference* is often convenient. First a weighing bottle containing a substance is tared to zero. Then some of the substance is transferred to a container to be used in the analysis, and the weighing bottle is weighed again. The negative display reading observed is the mass of the substance removed. The weighing bottle is tared to zero again, and the above process repeated until all desired samples have been weighed.

EXPERIMENTAL PROCEDURE

Note: This experiment is to be done individually.

1. Obtain three nickels from your instructor and place them in a clean and dry weighing bottle. After the nickels have been added, manipulate the weighing bottle using a strip of paper towel or a KimWipe and avoid touching the bottle with your fingers.

2. Determine by difference the mass of each nickel to the nearest 0.0001 g and record the values in your lab notebook. Calculate the *mean* ($\bar{x}$) for the set of three mass measurements as described below.

3. The precision of the set of measurements is indicated by the *standard deviation* (**s**) and the *relative standard deviation* (**rsd**) in parts per thousand (*ppt*). Calculate the **s** and **rsd** following the procedure below and record the results in your lab notebook.

    As with the three nickels just weighed, chemical analyses are usually performed in triplicate (or at least duplicate). This allows determination of a relative standard deviation and hence, a measure of the precision of the analytical results.

4. In subsequent labs in this course, it is recommended that standard deviation be calculated using a calculator or computer function instead of doing it by hand.

    Use Excel to check your hand calculations of $\bar{x}$ and **s** by entering the three nickel masses and using the Excel functions to calculate mean and standard deviation: =average( ) and =stdev( ). (See your instructor for help if needed.)

    Next, if your calculator has functions to calculate $\bar{x}$ and **s**, learn how to use them now. If you do not know how to do this then ask others using the same type of calculator or check the manual.

5. The accuracy of the mean is indicated by the *relative error* (ppt). Here we will assume the mass of each nickel should be 5.0000 g, and the accuracy indicates how close the mean is to this value. Calculate relative error (ppt) for the mean mass of the three nickels and record the result:

$$Relative\ error\ (ppt)\ =\ \frac{\left(\bar{x}-5.0000\ g\right)}{5.0000\ g}\times10^{3}$$

6. Finally, grade the U.S. Mint using the grading criteria listed on page 6 of the Chem 123 Lab Introduction packet. This grade reflects how closely the mint came to making these nickels' weight five grams. Assume the maximum grade is 20 points and that the U.S. Mint lost no other points. The precision and accuracy of your analysis of unknown samples in this course will be graded in a similar way.

Calculation of Results

Sample calculations for this exercise are given below. Be sure to use all five of the significant figures provided by the analytical balance in your calculations.

Suppose the weights of the three nickels were found to be 4.9935 g, 5.0242 g, and 5.0109 g. The *mean nickel weight*, $\bar{x}$, is,

$$\bar{x}\ =\ \frac{\sum x_i}{n}$$

$$\bar{x}\ =\ \frac{\left(4.9935\,g+5.0242\,g+5.0109\,g\right)}{3}\ =\ 5.0095\,g$$

The mean, of course, tells us nothing about how the individual measurements compare to each other. The values 9.6458 g, 5.0255 g, and 0.3573 g have a mean identical to the example above, but we would have grave doubts about a chemist who reported this range of weights for three apparently typical nickels, even though the mean value might be quite accurate.

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The precision of a set of measurements refers to how closely the individual measurements are distributed around the mean, and the *standard deviation*, **s**, is one way to represent the precision. The standard deviation of a set of N measurements can be calculated as follows.

$$ s = \sqrt{\frac{\sum \left(x_i - \overline{x}\right)^2}{n-1}} $$

The following table for the sample data above is useful.

	mass, x_i (g)	$\left|x_i - \overline{x}\right|$ (g)	$\left(x_i - \overline{x}\right)^2$ (g^2)
nickel **1**	4.9935	0.0160	0.000256
nickel **2**	5.0242	0.0147	0.000216
nickel **3**	5.0109	0.0014	0.0000020

The standard deviation is,

$$ s = \sqrt{\frac{\left(2.56*10^{-4} + 2.16*10^{-4} + 0.020*10^{-4}\right)g^2}{3-1}} = 0.015\underline{4}\ g $$

When a data set contains many measurements, and their deviations from the mean are random, it can be shown that any individual measurement has about a two-thirds chance of being within one standard deviation of the mean. For small data sets, as here with only three measurements, the standard deviation is a less reliable indicator of any individual measurement; however, we shall use it to represent the precision.

Finally, the *relative standard deviation*, **rsd**, in parts per thousand (ppt) is given by,

$$ rsd = \frac{s}{\overline{x}} \times 10^3 $$

For these data,

$$ rsd = \frac{0.015\underline{4}}{5.0095\ g} \times 10^3 = 3.\underline{0}7\ ppt $$

Laboratory Report

All data and results for this exercise must be recorded in your notebook as described on pages 1-5 of the Chem 123 Lab Introduction packet. In addition, you are to complete the Data and Results Summary sheet handed out in lab and turn it in at the assigned due date. Be certain to show proper units and significant figures on all experimental and calculated values. Remember that, as a general rule, you should always report standard deviation, relative standard deviation and relative error values to two significant figures, as in the example above.