

Error Analysis in the Chemistry Laboratory¹

The goal in the Chemistry laboratory is to obtain reliable results while realizing that there are errors inherent in any laboratory technique. Some laboratory errors are more obvious than others. Replication of a particular experiment allows an analysis of the reproducibility (precision) of a measurement, while using different methods to perform the same measurement allows a gauge of the truth of the data (accuracy).

There are two types of experimental error: *systematic* error and *random* error. Systematic error arises from a flaw in experimental design or equipment and can be detected and corrected. This type of error leads to inaccurate measurements of the true value. On the other hand, random error is always present and cannot be corrected. An example of random error is that which arises from reading a burette, which is somewhat subjective and therefore varies with the person making the reading. This type of error impacts the precision, or reproducibility, of a measurement. The goal in a chemistry experiment is to eliminate systematic error and minimize random error to obtain a high degree of both accuracy and precision.

Expression of experimental results is best done after replicate trials that report the average of the measurements (the mean) and the size of the uncertainty (the standard deviation of the trials). For a series of n trials, x_i , the average, \bar{x} , and the standard deviation of the trials, s_x are calculated using:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \qquad s_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

Excel easily calculates both. The standard deviation of the trials reflects the precision of the measurements. Whenever possible, you should provide a quantitative estimate of the precision of your measurements by reporting both the mean and standard deviation of your data. Sometimes it is most useful to report the relative uncertainty, which compares the size of the absolute uncertainty to the size of the associated measurements (the mean). The accuracy is often estimated by comparing your experimental mean to a literature value. This measure is often just called the experimental error. The percent relative experimental error is then:

$$\text{percent relative experimental error} = \left(\frac{\text{mean} - \text{literature}}{\text{literature}} \right) \times 100\%$$

The percent relative standard deviation can be calculated as follows:

$$\text{percent relative standard deviation} = \left(\frac{\text{standard deviation}}{\text{mean}} \right) \times 100\%$$

You should then reflect upon and discuss the possible sources of random error in your measurements that contribute to the observed random error. Sources of random error will differ depending on the specific experimental techniques used. Some examples might include reading a burette, the error tolerance for laboratory balances, etc. Sources of random error do not include calculation error (a systematic error that can be corrected), mistakes in making solutions (also a systematic error), or your lab partner (who might be saying the same thing about you!).

1. Material herein taken from *Quantitative Chemical Analysis, 5th Edition* (1999), D. C. Harris and *Chemistry, 5th Edition* (2000) by S. S. Zumdahl and S. A. Zumdahl.