EXPERIMENTAL ERROR

In the laboratory, NO measurement is exact. There are always errors that affect our results – whether we're using a 10-cent ruler or an $800 balance. When conducting an experiment, there are three types of errors that you will encounter: "human" error, random error, and systematic error.

Human error

A *human error* is simply another word for *mistake*, *blunder*, or *screw-up*. Examples include:

- Not setting up an experiment correctly
- Misreading an instrument
- Using the wrong chemical(s)
- Not following directions
- Spilling or general sloppiness
- Bad calculations, doing math incorrectly, using the wrong formula

Human errors are NOT a source of experimental error; rather, they are "experimenter's" error. **Do not quote human error as a source of experimental error in any lab report!**

Random Error

Random errors are unavoidable variations that will either increase or decrease a given measurement. Examples may include:

- Fluctuations in the laboratory balance (your sample may weigh a few hundredths of a gram higher or lower at any given time, depending on the quality of the balance and the conditions in the room).
- Using a stopwatch to time a reaction. (Regardless of how careful you are, you will sometimes stop the watch too soon and sometimes too late).

To minimize random errors, try to use high-quality laboratory equipment whenever possible and use consistent techniques when performing an experiment. Since random errors are equally likely to be high as low, performing several trials (and averaging the results) will also reduce their effect considerably.

Systematic Error

Systematic error is an error inherent in the experimental setup which causes the results to be skewed in the *same direction every time*. For example:

- A mis-calibrated thermometer may increase all temperature readings by 0.5ºC.
- A cloth tape measure used to measure the length of an object could be stretched out from years of use. (As a result, all of your length measurements would be too small).
- Substituting 10.00 grams of rock salt for 10.00 grams of table salt in an experiment will affect the rate at which the reaction takes place. In this case, the reaction rate would decrease due to the decreased surface area.

(over)

Since systematic errors always skew data in one direction, they can not be eliminated by averaging. However, they can usually be avoided by changing the way in which the experiment was carried out (using more reliable equipment, modifying a procedure, changing laboratory conditions, etc).

Error Analysis

The most common way to analyze experimental error is to compare your results with a known value (if available). Use the following data as an example:

Density of Water (from experiment)	Density of water (actual or known value)
0.993 g/mL	1.00 g/mL

In this case, the **absolute error** in the measurement is 0.007 g/mL. (In other words, the experimental value is 0.007 g/ml lower than the known value).

Another (and often more useful) comparison is known as **relative error** or **percent error**. It is calculated as follows:

$$\%\ \text{error} = \left|\frac{(\text{your value}) - (\text{known value})}{\text{known value}}\right| \times 100$$

In this case, the percent error would be:

$$\%\ \text{error} = \left|\frac{0.993 - 1.00}{1.00}\right| \times 100 = \textbf{0.700\% error}$$

Lab Report Guidelines for Error Analyses

An error analysis is an extremely important component of your formal lab reports. All error analyses must contain the following:

- ❑ A comparison between your results and the known value(s), if they are available. This should always include the relative error (% error).
- ❑ A minimum of **three** sources of experimental error with a specific explanation about how each error may have affected your result(s). Here are some tips:
  - Think about all measurements taken during the experiment and the instruments used to make those measurements.
  - Differentiate between random errors (which fluctuate up or down) and systematic errors (which skew results in one direction).
  - Avoid using vague terms such as: **changed, affected, disrupted, altered, or interfered.** If an error increases your final answer, you need to state it explicitly. If an error decreases your answer, you need to state it explicitly. If it's not clear whether an error increases or decreases your final answer, you need to state it explicitly!

Sources: David Dice. "Experimental Error." http://www.carlton.paschools.pa.sk.ca/chemical/Sigfigs/contents.htm
Tim Farris. "Experimental Error." http://www2.volstate.edu/tfarris/PHYS2110-2120/experimental_error.htm