C8 Being Significant and Watching Your Figures

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After attending this presentation, attendees will better understand the importance of the relationship between the accuracy of a measurement system and the number of significant figures used to report the results.

This presentation will impact the forensic science community by demonstrating the relationship between the demonstrable accuracy of a result and the defensibility of the data in legal proceedings.

A Google search of the term “significant digits” offers up a variety of definitions. They all boil down to this: significant digits are those digits in a number that can be defended based on the accuracy of the measurement system used to generate them.

Every analytical chemistry course includes a unit on precision and accuracy and a lesson about significant figures. Students are taught what they are, how to use them, and why they are important. When this lesson is forgotten, the illusion of greater accuracy than the analytical methods can produce is proliferated. For instance, when using a calibration equation to calculate a result, any number of digits and decimals can be produced, but only those that are representative of the method’s accuracy can be defended.

No analytical result can be more accurate than the factors used to determine it. In other words, if a balance that is accurate to 0.1 g is used to weigh a sample, a result of 0.11g cannot be defended because that result implies greater accuracy and precision than it was possible to achieve with the measurement system. Likewise, a calibration curve produced by analyzing standards at concentrations of 5.0, 10, 50, 100, and 200pg/mL cannot produce a defensible calculated result of 5.005pg/mL.

The last significant figure in an analytical measurement is the only figure that should express variance. For instance, a result of 1.6 reflects two significant figures and an error term of 0.1, meaning that the result could be 1.5, 1.6, or 1.7. The error term is expressed as 62 parts per thousand or 6.2%. If the same result is reported with three significant figures, as 1.62, a smaller error term is expressed (6.2 parts per thousand or 0.62%), meaning that the result could be 1.61, 1.62, or 1.63, but not 1.5 or 1.7. Supporting this level of accuracy and precision at this concentration range would require that the laboratory can routinely and demonstrably analyze two portions of a project-specific sample with duplicate agreement of less than one relative percent difference (RPD).

The second of the four non-exclusive factors that make up the criteria used to judge the validity of an expert opinion in a *Daubert* test asks, “Is there a known error rate or variability?.”[1]

Every measurement has an error term. Any measurement system will produce a range of results for a single sample when that sample is repeatedly measured for a given analyte. The known or potential error term is a statistical measure of how similar (or different) these results are likely to be. In analytical chemistry, the method includes the entire analytical procedure used to identify and measure the concentration of an analyte in a sample matrix. Some sources of error are unavoidable, while some sources can be minimized by following good analytical practices and sound quality control procedures. The objective of any experimental process should be to produce the most accurate result possible, i.e., a result with the smallest possible error term. The use of good laboratory practices and sound quality control procedures is essential in a laboratory’s effort to reduce the error term, but it cannot be eliminated. This measurement uncertainty is reflected in the number of significant figures used to report the results. It is critical to present results using only the significant figures that are appropriate to the data set. The error term implied by the significant figures must be supported by the available data and documentation and must be demonstrated to be repeatable for the results in the data set.

Reference:

1. *Daubert v. Merrell Dow Pharmaceuticals, Inc.* (1993) 509 U.S. 589

Significant Figure, Error Term, Defensibility